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NOVEMBER • 1938

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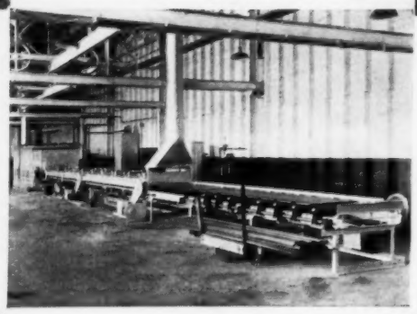
(Below) Various lengths and diameters of steel tubing are uniformly bright annealed in this special atmosphere furnace and automatically unloaded onto trucks.

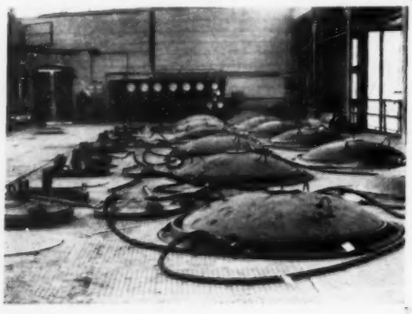
(Above) Another fuel-fired, continuous controlled atmosphere bright annealing furnace equipped with The Electric Furnace Co.'s new recuperative type, gas fired radiant tubes.



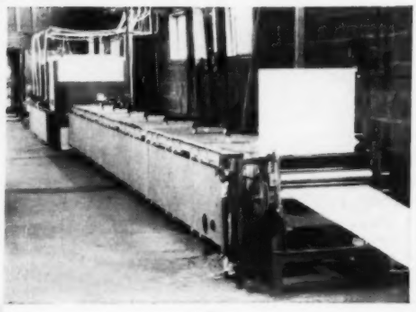
(Above) Special alloy rod is annealed without scale or decarburization in this electrically heated pit type furnace. One of several installations in a prominent steel plant.

(Below) The pit type furnaces shown below are used for normalizing and spherodizing rod, and bright annealing wire—Another "repeat order".

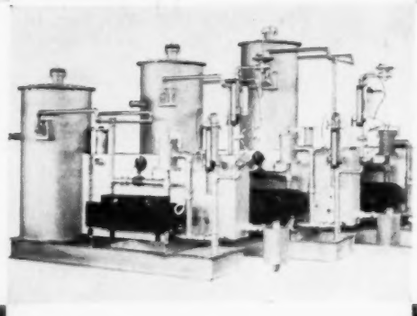
(Below) Bright annealing steel strip—continuously. Advantages include quicker deliveries, shorter annealing time, absolute uniform finish and anneal. These furnaces handle either narrow or wide strip.



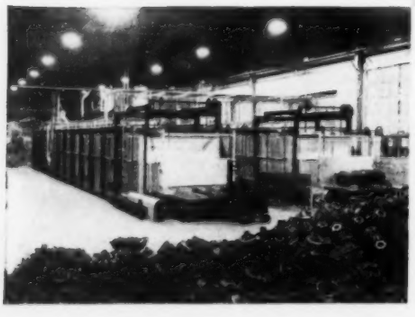
(Below) Three standard sizes of Elfurno generators for producing the inexpensive protective atmospheres used in controlled atmosphere furnaces. Elfurno generators are built for any capacity required.



(Below) Short cycle malleable castings are annealed absolutely scale-free in these two continuous special atmosphere electric furnaces. The annealing time was reduced from 165 to 35 hours. These furnaces handle 40,000 lbs. per day.



(Below) Bolts, nuts and miscellaneous other medium sized parts or products are scale-free hardened in continuous chain belt conveyor type furnaces similar to the above. This furnace handles 1000 lbs. per hour.



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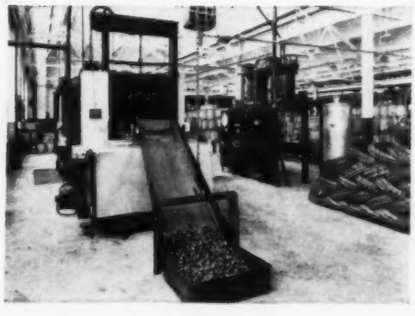

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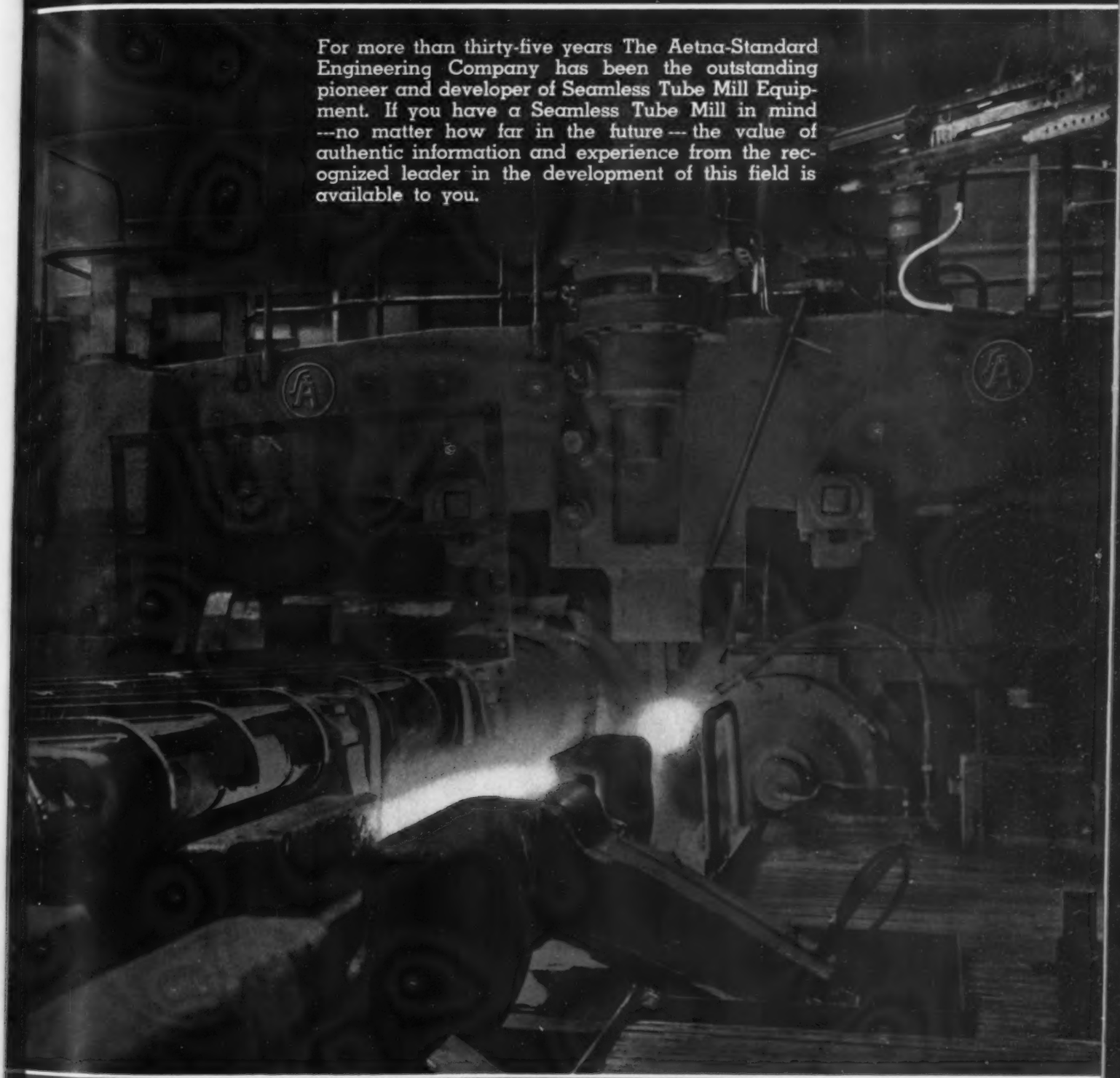

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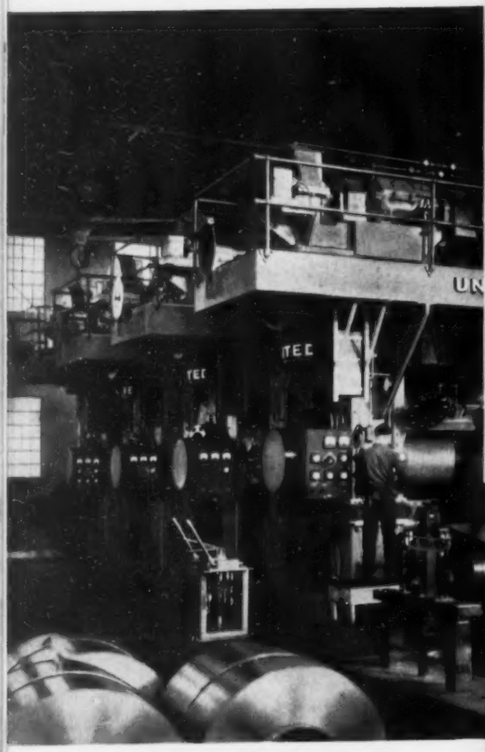

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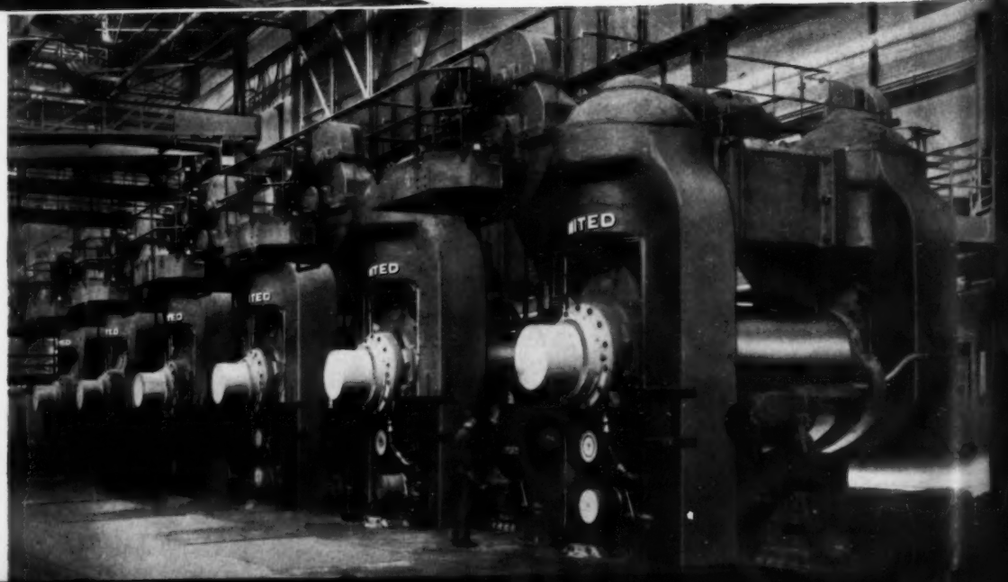
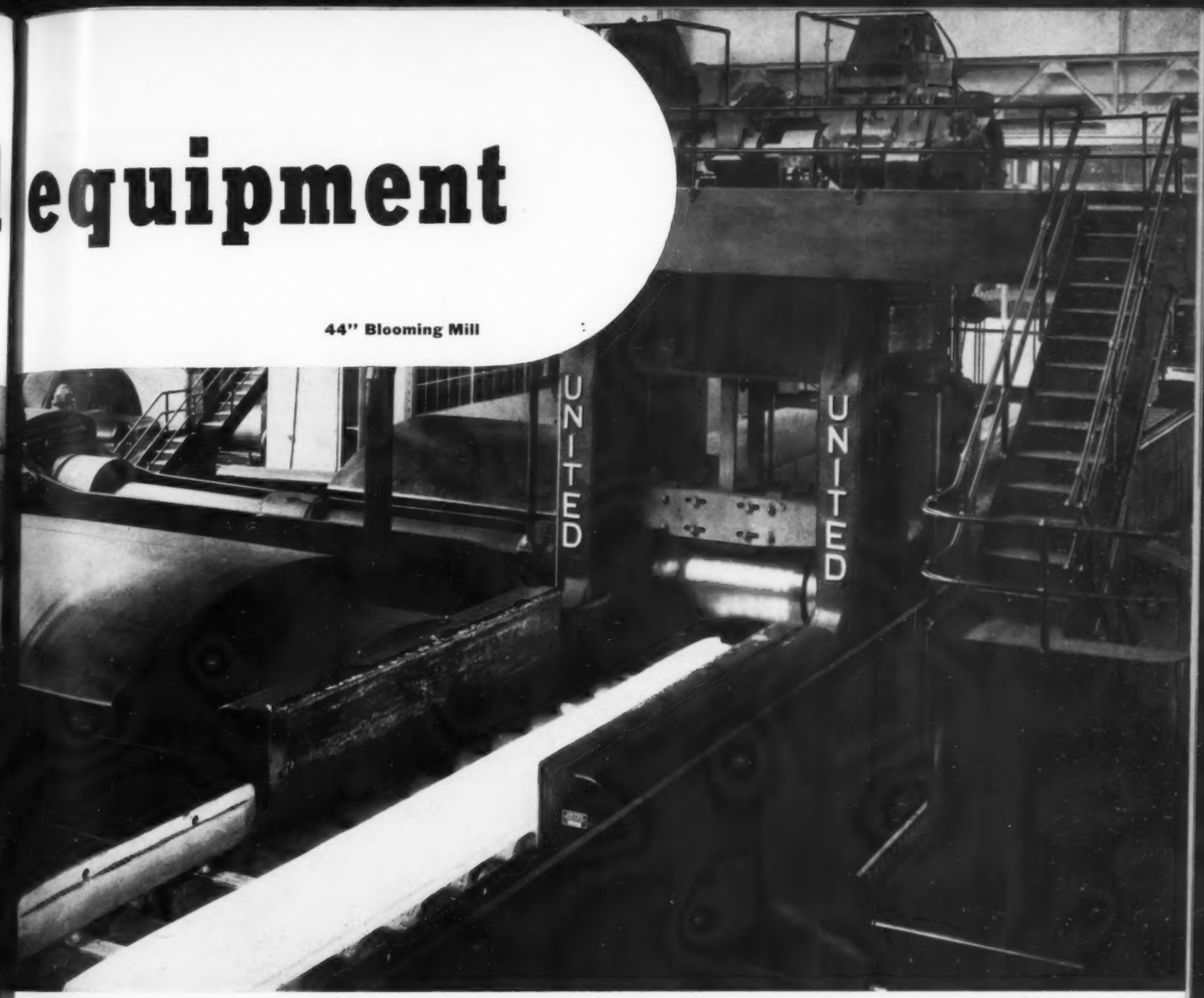


98" Continuous Hot Strip Mill

ll equipment

44" Blooming Mill



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12" 7-Stand Merchant Mill

Finishing Equipment for WIDE STRIP MILLS

By JOHN L. YOUNG, Manager Machinery Sales

UNITED ENGINEERING & FOUNDRY CO.

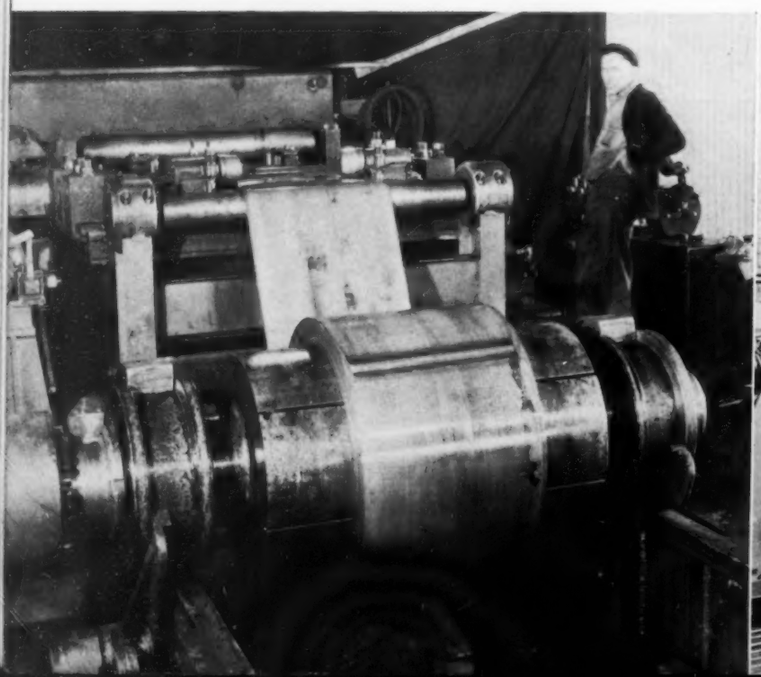
PITTSBURGH, PA.

Presented before the A. I. & S. E. Annual Convention, Cleveland, O., September 27, 28, 29, 30, 1938

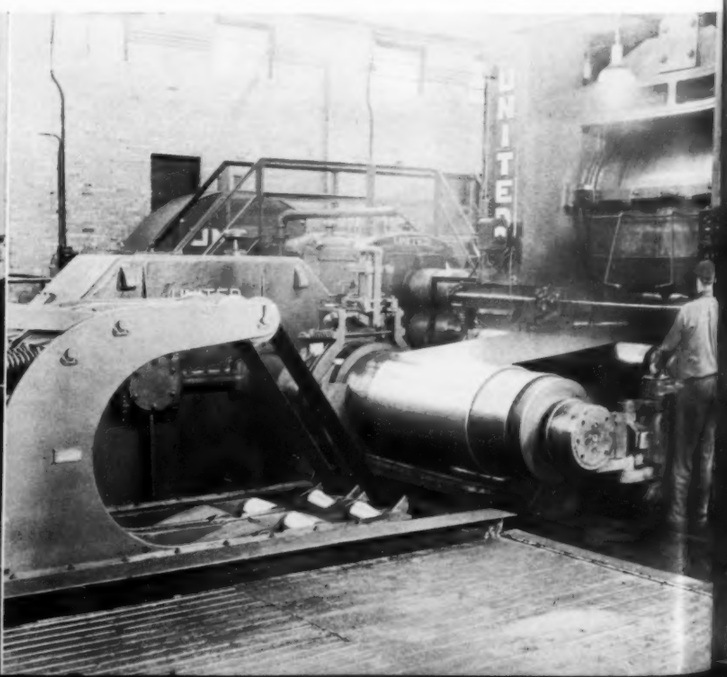
▲ STRIP mills have progressed and become faster, wider and more efficient and the processing and finishing equipment has also been developed in a similar manner to keep pace with the mills and to fill the requirements of the customers of the mills. These customers as time has gone on from slump to depression to recession, have gradually become more exacting in their demands for finish, metallurgical quality, roughness, smoothness, mirror finish, hardness, softness, dullness, brightness, squareness, ductility, stiffness and many other characteristics.

Just two weeks ago a well known steel mill official said to me that these continuous hot strip mills have ceased to be the secret and specialized art of design of a few years back and now one can almost get the necessary specifications for a hot strip mill out of a Carnegie handbook. There is a certain amount of truth in that statement, but I think he should have referred to the issues of the IRON AND STEEL ENGINEER over the last few years as that really has become the text book. However, we in the machinery designing business must keep a few jumps ahead of any text book and we generally have something up our sleeves to produce at the right moment and some of the features of the mills and processing equipment at the Corrigan-McKinney plant of the Republic Steel Corporation will bear me out in this statement.

Even since the installation of the equipment at Corrigan-McKinney, there has been further progress



Showing strip welded by automatic gas flame with ends clipped and being removed on mandrel for reversing cold mill.



77" wide tandem cold mill showing double belt wrapper away from and clear of tension reel.

John L. Young presenting his paper at the annual convention of the A. I. & S. E. at Cleveland, Ohio September 27-28-29-30 1938.

toward the production of a more satisfactory product both metallurgically, technologically and practically. If we don't profit by the lessons we learn, we never progress very fast or far.

While the hot strip mill has become more or less a text-book detail, the cold mill and the processing equipment is still open to further study and development. In that field lies our immediate future for study, research and practice.

This word "practice" has fascinated me for some time. My first real notice of the word came while in college and while living with a group of pre-medics and medics as well as potential attorneys, engineers, advertising specialists, bankers and whatnot. Truly, a doctor practices.

Webster says under the caption "practice", "any customary action or proceeding regarded as individual, habit—an established custom. The act or process of executing or accomplishing—the regular prosecution of a business pursuit requiring education, etc."

Some years later when I had the opportunity to work in a metallurgical laboratory in an attempt to learn the fundamentals of the making and shaping of iron and steel, I again learned that the rules of the metallurgist are very flexible and as such it was and is a tough job to get an exponent of that art to make a definite claim, recommendation, or statement. I did learn that certain basic laws have been established and they are being somewhat modified in detail as further practice is carried on, but on the whole we are arriving somewhere. Here again I have learned that the metallurgist practices, shall we call it the cut and try method, which in turn gives us our basic understanding for the rules in any job or profession.

Some individuals have thought it an advantage to keep one's individual knowledge a mystery to the group. Those days are passing. Have you noticed in the recent years how the rollers on a hot mill or a cold mill, as well as the technical experts, can talk intelligently on the subject of metallurgical properties and qualities? Association with the specialists and the demands of the customers as competition has become more severe has created this change and well it is, for as such as we can and will progress.

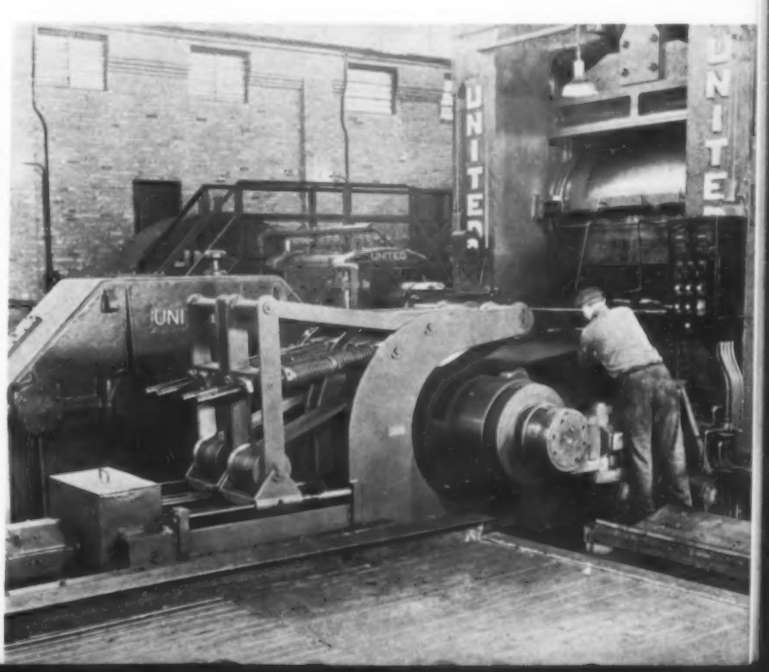
As those of us in the machinery design field develop new and better means for accomplishing the desired results, so must the operating personnel increase in efficiency and ability to equal the trend. No matter how good the tool, it is no better than the practice of the operator, who must understand and know how to run the tool he is given to work with.

This is exemplified in a great many of the steel plants today, especially the cold finishing departments. As you visit these plants, or as you meet the personnel of these plants, whether they be managers, superintendents, foreman or operators, note the trend during the last ten years toward a younger, more technically trained but practical group. No longer must a graduate of a technical school look forward to only a white collar job and pencil pushing. There is a wide field for those men in this cold reduction field.

The subject of this paper is "Finishing Equipment for Wide Strip Mills". It is my firm conviction and belief that the first and paramount requisite in this equipment is the proper personnel. The men who run the machines are as much a part of the equipment as the machine themselves.

So much for that phase; now let us consider the machines themselves as the next element of the equip-

77″ wide tandem cold mill showing double belt wrapper in position around tension reel receiving strip at mill delivery speed.



ment, but before proceeding with the equipment itself, here are a few summaries for which I am indebted to the American Iron & Steel Institute.

	Production of Hot Rolled Sheets	Production of Hot Rolled Strip
1926	4,237,479	1,222,089
1927	3,979,037	1,318,419
1928	4,962,410	2,161,988
1929	5,254,998	2,502,793
1930	3,511,557	1,941,862
1931	2,461,494	1,620,971
1932	1,471,532	1,185,184
1933	3,092,410	1,830,106
1934	3,202,605	2,196,840
1935	5,175,557	2,647,589
1936	6,995,905	3,224,916
1937	7,839,506	2,895,561

PRODUCTION OF COLD ROLLED SHEETS
(Gross Tons)

Finished on	1934	1935	1936	1937
Conventional sheet mills	427,214	539,111	448,217	268,782
Continuous or tandem cold reduction mills	515,255	944,881	1,281,284	1,841,721
Single-stand cold reduction mills	137,292	340,114	375,380	297,563
TOTAL	1,079,761	1,824,106	2,104,881	2,408,066

PRODUCTION OF COLD ROLLED STRIP
(Gross Tons)

Finished on	1934	1935	1936	1937
Conventional sheet mills	1,469	810	340	142
Continuous or tandem cold reduction mills	65,290	95,612	181,381	159,976
Single-stand cold reduction mills	311,703	474,450	658,305	615,042
TOTAL	378,462	570,872	840,026	775,160

Eighteen months ago the author read a paper before the Chicago and Buffalo groups of the Association of Iron and Steel Engineers titled "Mechanical Developments of Modern Cold Rolled Strip Mills" and at that time referred to some new developments for strip mills including strip welding, belt wrappers, electrolytic cleaning, and the rotary pickler.

Republic's 98" hot and cold strip mill was under construction at that time and was also briefly outlined.

STRIP WELDERS

Since that time a number of strip welders have been placed in service. These are both gas and electric flash type welders. Both have their fields, with the gas apparently making the best commercial weld. The flash weld, however, allows a time cycle that is one-half to one-third of the gas weld cycle, making possible its installation in pickle lines or as a part of the newly developed and patented continuous cold rolling reduction mill arrangement.

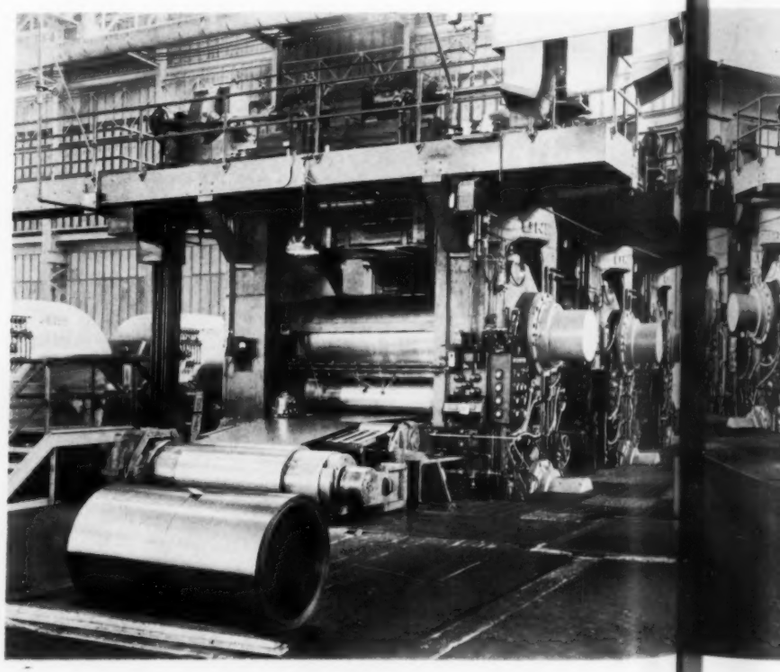
The automatic gas welder requires a complete shearing and welding cycle of from 3 to 6 minutes.

The electric flash welder has a full cycle of from 1¼ to 3 minutes.

The tendency in the further development of these welders, both gas and electric has been toward the complete automatic cycle, that is, the original welders had separate shears to square the ends before matching the ends for welding. The latest development is to clamp the two ends of the two strips to be welded and after clamping, shear both ends at the same time for matching. After the shear has performed its function, one of the clamp heads moves forward in the electric machine and performs the welding operation without reclamping and without rematching.

From that point on the tendency is further toward complete automatic control and it is desirable to remove the flash formed by the electric weld as soon as

98" 3-stand tandem cold mill showing adjustable feeder guides between delivery stand and tension reel for automatically entering the front end of the strip in the automatically positioned reel gripper.



possible and while still hot. The latest machine includes a clamp with a definite stroke that is placed in position on the leading strip during the welding cycle. As soon as the weld has been completed, the welding clamps are relieved and the gripper clamp pulls the strip through the snow-plow flash trimmer. These operations are all controlled from the desk or the operating pulpit.

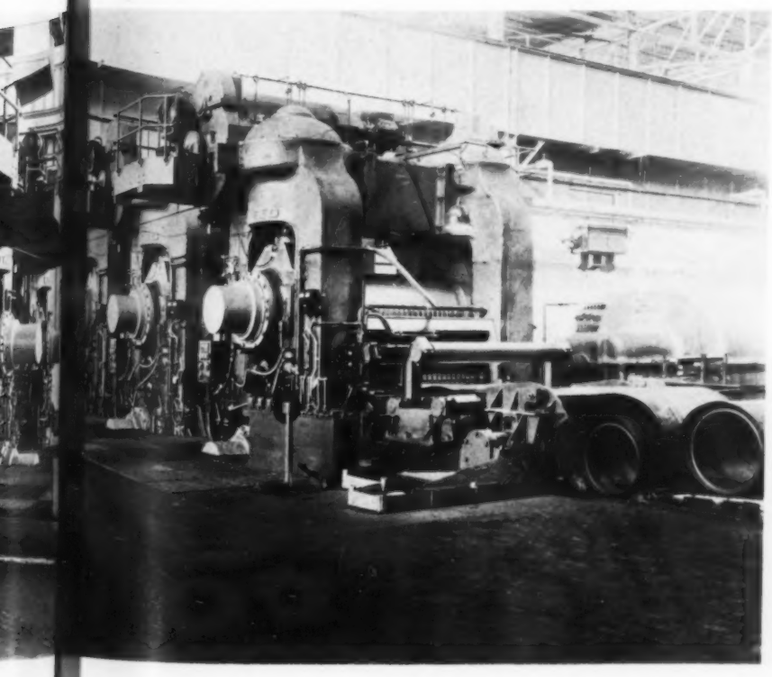
This pulling or gripper clamp has a definite stroke that stops the trimmed weld at a point where the side clippers can remove the unmatched ends in the form of a half moon. This not only matches the two ends but also removes the excess flash that is left at the end of the weld.

As soon as the ends have been trimmed, the next development is to move the weld into position for annealing by gas flame immediately ahead of the pinch rolls at the delivery end of the machine. These rolls are made large enough to slightly roll down or mash down the heated weld and eliminate some of the bump that is present from the flash trimming since the flash trimmer does not remove the flash down to the exact thickness of the parent metal. Furthermore, the two ends of the strip are generally different in thickness and this flattening effect tends to help the rolling condition later in the cold mill.

Another thought in this connection is to make a diagonal weld on an angle of about three degrees. The theory back of this idea is the elimination of the bump on the mill rolls across the full width of the strip. This diagonal or skew weld goes into the mill rolls gradually and thereby prevents the sudden impact.

The automatic gas welder requires no flash trimming, nor successive annealing; therefore, the above problem is not present in that method, although the skew weld is used. The time cycle of the gas welding operates against its commercial use in a continuous operating line where the cycle is required at a minimum.

98″ 3-stand tandem cold mill showing the feeder type uncoiler with the coil receiving cradle rolls, cone type uncoiler, and feeder type pinch rolls.



CONTINUOUS ROLLING COLD REDUCTION MILLS

The development of the continuous rolling cold reduction mill, while not new on paper, is new from the practicable standpoint. The time cycle of the strip welder is the key to the successful operation of the unit. The development of a quick acting, dividing flying shear and strip deflector arrangement for the delivery end has also been a problem, but it now seems to be solved. Double collapsible tension reels with belt wrappers serve as the final step in this continuous process. All of the improvements embodied in this development are covered or are in the process of being covered by patents. It is quite likely that at least one of these four or five stand tandem units will be placed in operation in 1939.

BELT WRAPPERS FOR WIDE COLD MILLS

Two double belt type belt wrappers have been placed in operation during the last eighteen months. The first unit was installed on a 3-stand 56″ tandem cold mill to handle material up to 50″ wide and up to No. 20 gauge. The stripper of the collapsible tension reel was not disturbed by this arrangement and the thought was to use the gripper for gauges heavier than No. 20 and the belt wrapper for the No. 20 gauge and lighter. The belt wrapper was found to be entirely successful for this set-up and an immediate increase of 15 per cent in mill production was obtained through the installation of this unit.

The second unit was installed on a 77″ 3-stand tandem cold mill. It has handled successfully and in regular production cold reduced strip up to 67¾″ wide x No. 20 gauge; 60″ wide x No. 16 gauge; and 48″ wide x No. 14 gauge.

A report from this mill states that they are getting more tonnage with less difficulty of stripping the coil from the reel.

Two belt wrappers for wide tandem cold mills are now under construction.

At Corrigan-McKinney, there is another development at the delivery end of the 3-stand 98″ tandem cold mill. This arrangement of the tension reel with suitable adjustable feeder guides makes it unnecessary to feed the strip by hand into the reel gripper. The strip follows the natural contour of the guides into the open gripper that has been automatically positioned. This is a definite step forward toward the reduction of delay at the reel. A similar unit has been installed on an 80″ 3-stand tandem cold mill.

FEEDER TYPE UNCOILERS FOR WIDE MILLS

At the entry end of this same 3-stand 98″ tandem cold mill at Corrigan-McKinney, there is a feeder type uncoiler which was described by the writer in his paper last year. It has been found possible with this feeder uncoiler to prepare a coil for entry into the uncoiler

and through the mechanical arrangement have the leading end of the trailing coil overlap the trailing end of the leading coil for immediate entry into the first stand of the tandem mill as soon as the trailing end of the leading coil has left the uncoiler.

Through a pinch roll arrangement and with driven cradle rolls on the hydraulic elevator, the trailing coil is fed into the mill rolls while the cones of the cone type uncoiler are taking their position to support the coil. After the cones have supported the coil, the hydraulic elevator is lowered and moved back into position for the preparation of the next coil.

ELECTROLYTIC CLEANING OF STRIP

The use of electrolytic cleaning for strip in tin plate gauges has become standard practice. Line speeds have been stepped up in the last few years from 500 fpm. to 1500 fpm. This increased speed is made possible by an improved method of conducting the current to the strip. This new method allows the passage of current into and out of the strip alternately to obtain the necessary electrolytic action. Voltages and amperages have been stepped up correspondingly to accomplish this result. The best results seem to be obtained with each generator delivering 2500 to 3000 amperes at 16 to 18 volts with the tank solution maintained at 6 to 8 per cent alkalinity based on titration with normal hydrochloric acid.

One wider line for strip sheet gauges has been built, but has not yet been placed in operation. This line, of course, will have a much lower operating speed than the tin plate lines due to the width of material and the gauges to be handled.

The use of Ward-Leonard control for the synchronization of the pinch rolls, tension rolls, and tension reel at the delivery end of the cleaning line has also been an important step toward the development of the higher speeds due to the definite regulation that can be obtained through that system. The use of the tension rolls also allows a definite control of the looseness or tightness of the coil being wound on the tension reel so that it is in proper condition for annealing in coil form without further loose coiling.

Another development in connection with the tin plate line is a strip feeding device. This unit consists of a series of chains and is either hand cranked or motor driven. The chains operate between the grids. If at any time the strip should break, either before or in the electrolytic cleaning tank, the leading end of the trailing strip may then be clipped to this chain and by driving the chain it can be pulled between the grids through the electrolytic tank and out at the discharge end where it may be fed through the pinch rolls, tension rolls, and onto the reel in the usual manner.

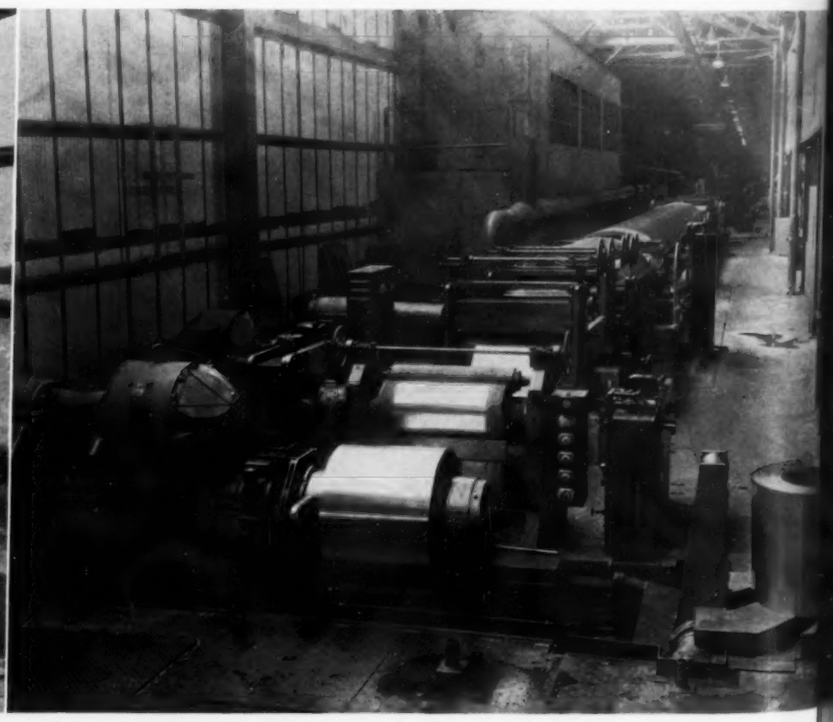
The development of the strip feeder makes it unnecessary for the operator to get into the electrolytic tank for feeding of the strip between the grids.

STRIP PICKLERS

The rotary strip pickler was described in the writer's paper of last year. That type of unit is limited to the wider strip and to comparatively light coils.

38″ electrolytic cleaning line showing the entry end with the uncoiler and seam type welder.

38″ electrolytic cleaning line showing delivery end with tension rolls and tension reel.



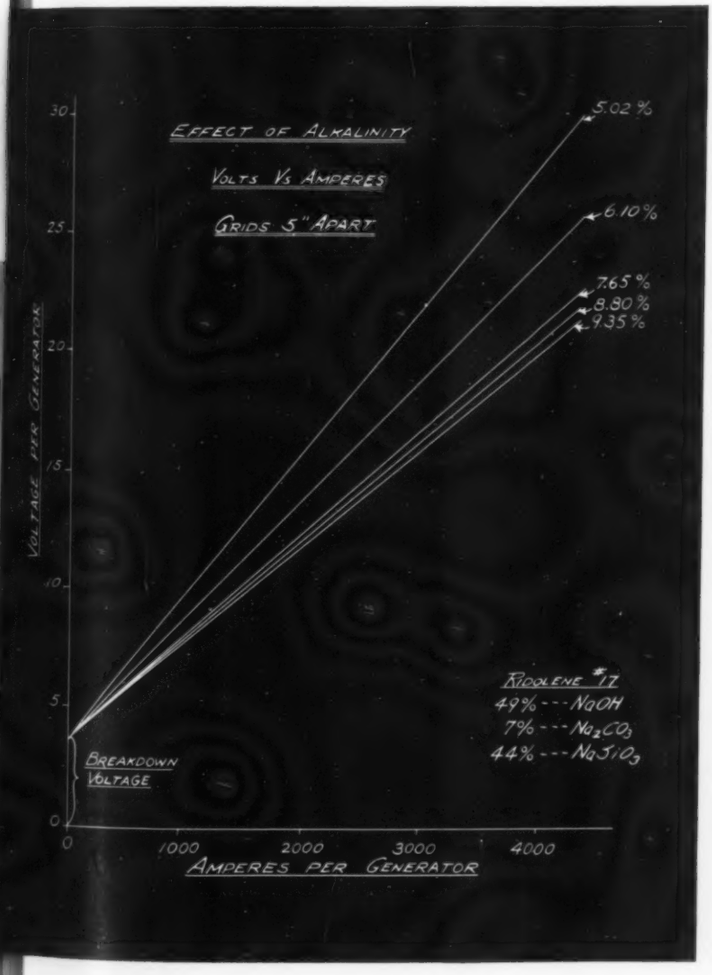
There has been a need for a continuous or high production pickler for narrow strip. The multiple strand continuous pickler presents certain complications, especially in operating efficiency and of course, in the floor space required.

A pickler of an entirely new principle has recently been developed for the narrow strip ranges and those up to about 24″ wide. This new unit will be quite flexible and will require a minimum of floor space. It is a single stand continuous unit based upon the cork screw principle. The arrangement allows the use of a strip welder ahead of the tanks and a recoiler at the discharge end. It not only serves as a pickler but also allows the welding of strip into larger coils for further processing in the cold mill.

In a layout recently prepared for handling strip up to 24″ wide, the entire floor space required for the unit is 70′ x 25′. This unit consists of an uncoiler, seam welder, looping pit, acid tank, cold rinse tank, hot rinse tank, shear and recoiler.

For strip 6″ to 14″ wide, the speed of the unit is 150 fpm. and for strip 16″ to 24″ wide it is 100 fpm.

Chart showing relationship of volts and amperes with various alkalinities in electrolytic cleaning.



The estimated production of the unit varies with the width and gauge. For strip 6″ wide x 16 gauge, the estimate is 6 tons per hour. For strip 24″ wide x .140″ thick, it is approximately 34 tons per hour.

Two continuous strip picklers at Corrigan-KcKinney are built along the conventional lines. One of these lines has an extra large looping pit after the stitcher to allow the installation of a strip welder at a future date.

These two lines are designed to operate at a maximum speed of 160 fpm. If 80″ or 90″ material of approximately 14 gauge could be available for running at all times through the picklers, about 700 tons per turn could be pickled on each line, but as the average width at Corrigan-McKinney will be between 40″ and 60″, probably half this tonnage would be a more reasonable figure. Tonnage, of course, from any pickler depends entirely upon the width and thickness of the material in process at the time.

The tanks of these picklers are wider than any steel brick lined tanks that have been installed in a continuous pickling line to date. They are 106″ inside the brick work.

Uncoilers are used at the entry end of each line. These are adapted to prevent coil breaks as the strip is uncoiled. These uncoilers also assist in loosening the scale and promoting rapid pickling.

The equipment is arranged to provide for continuous movement of the strip through the pickle tanks while stitches are being made at the entry end and cut out at the exit end.

Special roller type side guides are used, which guide the strip through the line with no damage to the edges of the strip and with minimum wear on the guides.

The equipment is installed at different levels to provide for the easiest possible charging of coils from the coil storage floor and for the discharge of coils to the chain type roller conveyor at the delivery end. This conveyor transfers the coils through the annealing building to the cold reduction department. The elevation of the equipment of these lines provides space underneath all the tanks for inspection and painting.

All tanks, fume lines, exhaust equipment and sewers are rubber lined to give protection against the acid.

DRY PICKLING OR CLEANING OF SHEETS OR STRIP

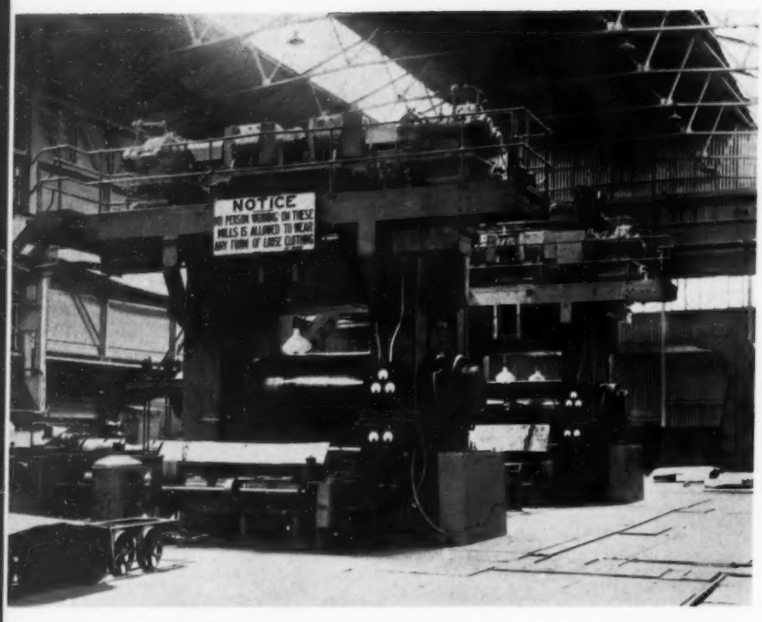
Another development along the lines of scale removal of hot rolled strip has been the dry process or the abrader. One of these units has been installed and is in regular production in this country.

There is a definite field for such a process where cold reduction mills are located within the city limits and the acid fumes and acid disposal becomes a real problem.

Further development along this line is now in progress and it is to be expected that this development will be looked upon with favor in the very near future.

It is also quite possible to look forward in this development to the further use of this process in line with the continuous cold reduction mill principle described previously in this paper. Several different types of equipment are being developed.

One unit now under development can also be used



80″ 2-stand tandem 4-high cold mill in England for producing full finished sheets.

for resurfacing steel strip and sheets, and to take scale off non-ferrous plates and bars.

COMPOSITE OR CLAD METALS

It appears necessary to take into consideration the possible effect on finishing equipment of the definite trend in the direction of composite or clad metals. There has been distinct progress in the last few years in electro-deposited metals and strip steel with copper, nickel and even brass surfaces. This material is now available and on the market. The material is cold finished to an excellent surface and meets with customer acceptance. Sales of such an attractive product in the field of composite metals will naturally lead to further exploration and development.

It is conceivable that material of tin plate thickness might be made with a surface of 18 per cent chrome and 8 per cent nickel and that 40 pounds of alloy per ton of steel would be sufficient to make the material usable for many purposes which tin plate and galvanized plate are now used. No small part of the success of such a venture would rest on the ability to finish the material without expensive grinding.

A number of companies are now working on the development of such a process and it seems reasonable to believe that the next few years will show real progress in this field.

FOREIGN COLD ROLLING

Up to the present time, strip in coil form from continuous hot mills has not been available in England or on the Continent except that imported from the United States.

Two interesting wide cold mills have been installed abroad in the last few years that are reducing the available hot rolled product in a satisfactory manner.

One of these mills is at John Lysaght Limited, Newport, Mon., England. It is a 2-stand tandem 80″ 4-high cold mill arranged for the addition of one or more stands in tandem at some future date.

This mill was built in England based upon American design.

The purpose of this tandem mill is to reduce 2-high hot sheet mill breakdowns to lighter gauges for high grade automobile sheets of deep drawing quality and with uniformity of gauge.

The breakdowns are end sheared, pickled, and then given one or two passes through the tandem mill as may be required for the desired finished gauge. These breakdowns average .070″ in thickness and are up to 72″ wide. They are usually reduced to .037″ in one pass if up to about 3′ wide and two passes for wider material.

Yields are as high as 92/94 per cent covering all losses. The average yield is around 85/90 per cent.

After cold rolling, the sheets are roller levelled, sheared, box annealed and skin passed. No normalizing has been found necessary. However, some difficulty has been experienced in the color of the sheets due to the mould pickling and grease spots on the sheets.

While this is looked upon as a rather difficult process, it is interesting to note that the process has been successful and we are informed that the product is of high quality.

The other mill is at the Renault Company in France. It is a single stand 72″ reversing cold mill arranged for the production of a similar product. The process at Renault is to produce plates approximately .118″ thick by approximately 32′ long on a conventional 3-high plate mill.

72″ reversing cold mill in France showing entry side with feeder type uncoiler procucing cold rolled strip from welded plates.

These plates are sheared, matched, and welded together by carbon arc welders. With two welders, they weld from 4 to 10 plates into a continuous strip and they average about 6 plates. These welded plates are then coiled in a 3-roll upcoiler. They are then pickled or cleaned by a recently installed wheelabrador and then given one pass through the reversing 4-high cold mill into another 3-roll upcoiler.

They will run between 50 and 100 coils through the cold mill for the first pass, recoiling them as outlined above, and store them for further processing in the same mill. After this group of coils has been given the first pass, the mill rolls are changed and they then proceed to further cold reduce the coils in their usual reversing method with tension reels. The first pass is made with tension only on the delivery side, but the successive passes are made with tension on both sides. Generally a total of four passes are given in this reversing cold mill.

It is interesting to note that they operate this mill even on the first pass without slowing down at the time the weld passes through the mill rolls. On this first pass they will average about 150 fpm. and will generally take about a 30 per cent reduction.

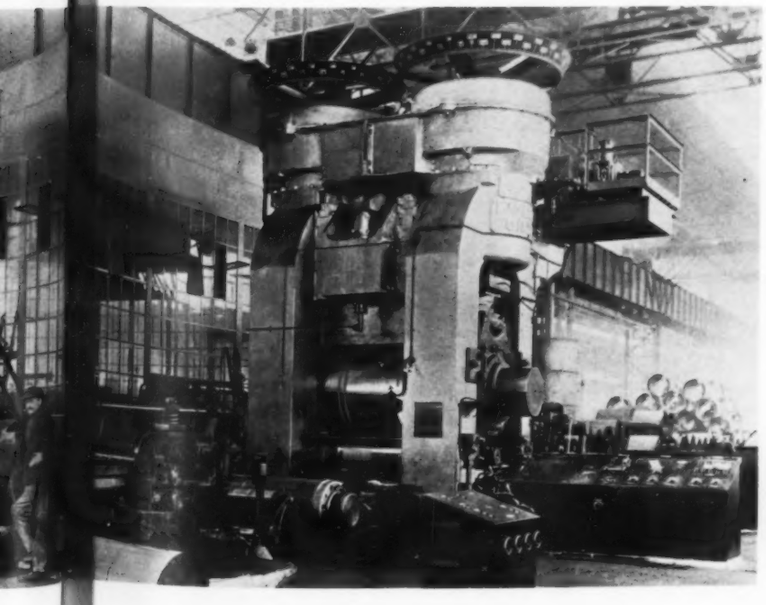
The cold reduced coils are then sheared to the proper sheet length, levelled, washed and dried, box annealed, and skin passed on conventional 2-high skin mills. After the skin rolling, they are again roller levelled, inspected, oiled and sheared.

At the present time production is up to between 12 and 14 tons per hour and the average yield is between 90 and 92 percent.

Welding breaks average less than 2 per cent.

We are informed that this process is highly successful and as such is producing the finest auto body sheets on the Continent.

72″ reversing cold mill in France showing delivery side with tension reel.



Hand gun type spot welder for sticking the loose ends of the cold reduced strip in coil form.

SPOT WELDERS

An interesting development of the last few months is a spot welder for fastening the inner and outer wraps of a cold reduced coil.

The first unit of this type is being used on a tin plate electrolytic cleaning line in the following manner:

The coils are stripped from the collapsible tension reel and delivered to an industrial tractor. Before the coils are moved away from the line, the spot welder is used to tack the two outer wraps together at the end of the outer wrap of the strip. In a similar manner the two inner wraps are tacked together.

This prevents the unwinding of the coil and eliminates the necessity of banding.

We have been further informed that these tack welds do not interfere in any way with the rolling operation nor have they found any instance where these welds have marked the mill rolls. In general, it is reported that this method of holding the coils together has been found entirely satisfactory.

The subject is so broad that it has been possible to mention each selected subject only casually. There are many more subjects on cold mill finishing equipment that could justifiably be discussed at length and in detail, but time does not permit.

It is hoped that the few that have been discussed will show the present tendency in development and design that is before us.

Further information about the Corrigan-McKinney installation, such as speeds, horsepowers, mills, finishing equipment and other interesting units are covered in detail in the September issue of the IRON AND STEEL ENGINEER.

DISCUSSION

PRESENTED BY

R. J. WEAN, President, The Wean Engineering Company, Warren, Ohio.

E. W. PLUMLEY, John Lysaght, Ltd., Newport, Mon., England.

J. A. CLAUSS, Chief Engineer, Great Lakes Steel Corporation, Ecorse, Michigan.

R. J. WEAN: Mr. Young's statement that the monthly issues of IRON AND STEEL ENGINEER over the last few years have become the textbook for strip mills is one in which I heartily concur, for I believe that the various papers and articles printed in IRON AND STEEL ENGINEER are the most comprehensive technical discussions dealing with the installation of strip mills throughout the world; and to anyone wishing to familiarize himself both with the construction and with the operation of strip mills, these various issues certainly could be referred to as a textbook.

Notwithstanding that Mr. Young has presented an excellent survey on the various phases of finishing equipment, I would like to discuss his remarks and discuss some of the items that were not mentioned in his paper.

Flexibility—which I term the ability to turn out a wide variety of orders in a minimum time and at a favorable cost—must of necessity be given a great deal of consideration when finishing equipment is installed in a steel mill. High speed and high production units do not pay their way if, a large portion of the time, they are standing idle because they are capable of handling only certain classes of orders. "Mass production" bias is a thing that must be avoided if flexibility is to be present in the facilities for finishing hot rolled strip, and engineers in planning a mill must be prepared not only for the wide variety of orders which their sales department may tell them are available but must be prepared for an appreciable change in the orientation of demand for steel products which can be brought about by changes in the basing point of prices, re-adjustment of fright rates, unfavorable legislation and an unfavorable attitude of labor.

I noted with interest Mr. Young's remarks about the welding of strip steel for the building of large coils or continuous strip. We have had no experience with gas welding, our experience dealing largely with electric welding. The time mentioned by Mr. Young of 1¼ to 3 minutes for a weld seems quite in line with practice, depending upon the width of material being welded. Full agreement cannot be given to the statement that notches on the edges of the weld should be used, for in my opinion if the width of the leading strip is greater than that of the strip that is being welded to it, I would consider the notches as being detrimental and only to be used to relieve the edge of the incoming strip when the leading part is narrow.

Mr. Young also states that the flash trimmer does not remove the flash down to the exact thickness of the parent metal. Observation would indicate that this is practically impossible with a plow type flash remover, but is nevertheless highly desirable and can be accomplished with the draw cut shaper type of flash trimmer. Welds can be trimmed down to the actual thickness of the base metal and this definitely removes the strain when these welds are later processed or pass through the cold mill.

Reference is also made to the fact that it is necessary to anneal the weld so that the weld will withstand cold reduction without breaking. While we are not prepared to say definitely that welds need not be annealed, on a recent test of operation metal was reduced on a tandem cold mill to tin plate thickness at a sheet of 1800 f. p. m. without such annealing having been done.

We have not found diagonal welds to be of any particular value or advantage if the straight welds are properly made and trimmed.

Mr. Young's discussion on continuous picklers dealt with the Corrigan-McKinney installation and gave a maximum speed of 160 f.p.m. I think it is well to mention that continuous picklers having four 60-ft. tanks are in operation up to 240 f.p.m. and have averaged 200 f.p.m. over a month's operation. The most important consideration in connection with continuous picklers is that they can be operated continuously and at a constant speed. By doing this, unbelievable tonnages and costs can be obtained.

Many of the present continuous pickler installations have special features giving low acid yield, uninterrupted operation, and one of the nice points is that the application of oil to the strip is now being accomplished in such a manner as to keep the floors in much better condition than in years past, there being no surplus oil to drip off as the coils are being transported.

I would like to confirm Mr. Young's statement concerning abrading equipment for removal of scale, since additional installations have been made throughout the industry during the last year for treating sheets and bars, but no installations have been made for the treatment of strip steel. The very low costs now secured in connection with continuous pickling make it increasingly difficult for abrading to compete as a direct scale remover. However, in future years it is quite probable that abrasive methods may be used for securing finishes that will be desirable to the customer for subsequent treatment such as painting, enameling, etc.

Following are some of the items not mentioned in Mr. Young's paper and I will treat them briefly:

(1) High speed flying shears have been developed permitting accurate cutting of steel at speeds up to 500 to 600 f.p.m. While speeds of this kind cannot be used for cutting wide strip steel such as produced at Corrigan-McKinney works, they can be used on lighter gauges and particularly on tin plate. The cutting of tin plate requires accuracy at extremely high speeds and development of a synchronized rotary flying shear has permitted a tolerance of 1/64″ plus or

minus. In addition to this, a synchronized shear eliminates the upsetting action or "burr" at the cutting edge so commonly present on shears that are not synchronized.

(2) Patented processing uncoilers are used both in line with other items of equipment such as pickling and as a separate treatment where it is desired to impart a state of cold plasticity to hot rolled strip sold without subsequent cold reduction. Products generally served are such as drum and barrel stock, although we are informed that some automotive requirements also call for treatment of this kind.

(3) No mention was made of annealing equipment and in all probability it is fair to say that the majority of strip product is being annealed in bell type radiant tube furnaces, and naturally we prefer the vertical tube type. For an equivalent tonnage, total capital investment when using this type of annealing equipment, is lower than the stationary type of furnace, taking into consideration all of the heavy bases, covers, charging equipment, etc. generally used. The corrugated inner covers used with the bell type furnace have come into general use and are more economical from a standpoint of original cost, replacement and fuel consumption.

Continuous annealing is being done on both light gauge material and auto body stock. This has not come into common use but will undoubtedly receive more consideration in the future.

Cold reduced strip for tin plate purposes is being continuously annealed by a large producer and consumer in the Baltimore area and it is believed that this type of furnace can be installed at an equivalent capital investment per ton with an equivalent operating cost as compared to coil annealing now practiced.

It is obvious that there are certain definite advantages in continuous annealing, but it might be well to mention a few; namely,

(a) Material properly treated in a continuous furnace should have uniformity from edge to edge and from end to end.

(b) The type of annealing can be predetermined so that the subsequent temper passing can be regulated to secure the proper temper without excessive cold passing.

(c) The time required for finishing material is, obviously, shorter on this type of equipment than when the work is done in coiled form.

Co-operation on the part of metallurgists, operators and customers will undoubtedly lead to a wide, successful use of continuous heat treatment, and much can be expected in this direction for the next few years.

(4) Much of the product from continuous mills is subsequently coated, such as tin plate, terne coating and galvanizing. The bulk of these products are still being produced by cutting the material before coating. However, this also will probably be subject to considerable change over the next few years. Continuous electrolytic deposition of tin is being practiced and a limited amount of this type of tin coated strip is being marketed. Research and experimental work now being conducted convinces us that continuous hot coating of strip for tin plate with a coating of ½ pound per base box and up is possible. Zinc, or commonly called galvanizing, coatings are being improved and steps are being taken to produce galvanized sheets with a very low zinc-iron base, which coating will be extremely tight and flexible.

One of the outstanding impressions one gains from visiting and hearing about strip mills is that truly the small producer has become the "forgotten man". There is a definite and distinct field for a modified strip mill capable of producing 10,000 to 15,000 tons per month. I am firmly convinced that such a mill can be built at a cost that will permit production of this limited amount of steel on a competitive basis. Recently I visited a mill in Canada where strip is made on one mill from a slab ingot with one heating. Material is reduced to 12 and sometimes 14 ga. thickness. This would seem to be the extreme minimum mill as compared to a continuous large wide strip mill capable of producing from 50,000 tons per month up. It would certainly seem that some place between these two extremes there can be devised a unit for the so-called "small" producer.

For years I have championed the cause of this group and am of the confident belief that something can be developed to take care of its needs.

J. A. CLAUSS: Mr. Young mentioned at the beginning of his paper that the magazine IRON AND STEEL ENGINEER, published by our Association, has become the Steel Mill Handbook. I want to say a few words for this magazine. Of all of the technical magazines, I believe that we of the Steel Industry read its pages more carefully than any other magazine. There is a reason for this. First, it publishes articles describing equipment and methods in which we are vitally interested; secondly, its articles are generally written by men whom we may know personally or who are known to us from their accomplishments; and, thirdly, it is our magazine in which we have a personal interest because we own part of it through our membership in the Association. So that this magazine will always stand first in our choice, I would urge the rank and file of our membership to take an active part in the discussion of the papers presented. If you are not prepared to discuss the papers when presented, or are too timid to talk on your feet, you can always write out your discussion and send it into the home office. This is your magazine and it will be just as good as you make it.

It is gradually seeping into the consciousness of our people that men are more important than machines. The best machine that we can design is just so much iron and steel and of little value unless we have a human operator. We are getting smarter, because we are getting away from the "high hat" stage. We're finding that it pays to go down into the mill and talk with the men who operate the machines that we design and tell them all we know about them and the reasons and why for of it. You can learn a great deal from the operators and you will find that they are pretty good fellows.

Our experience at Great Lakes with a flash welder in continuous pickling lines indicates that annealing of the weld after the flash has been removed is not necessary. A paper on this subject was read yesterday afternoon. I am unfamiliar with the continuous

rolling cold reduction mills. Experience has taught me that it is not always wise to put into one continuous line too many operations.

Belt wrappers are a welcomed improvement. We are installing one on our 96″ 3-stand tandem cold mill. Anyone familiar with the difficulty of opening and feeding material from coils will welcome equipment which will lessen the labor for this operation. The use of feeder type uncoilers for wide mills is not general at present.

I would like to know more about the new equipment for continuous pickling of narrow strip. How the cork screw principal mentioned by Mr. Young works is not clear to me.

There is room for further development of the Wheelabrator for cleaning and scale removal. We have used the Wheelabrator for cleaning narrow slabs and billets with success. There is no reason why it should not work on sheets; the low production per unit is at present a handicap.

While Mr. Young's paper is rather general in its scope, he has given us much food for thought.

The handling and finishing of wide strip sheets is worthy of the earnest thought of all steel mill engineers and I hope we will hear further on this subject.

E. W. Plumley: I was given to understand by Mr. Young that anything I would say was going to be in reply to leading questions about this plant which has been installed at our works at Newport. This, however, is being modified, and it seems that I am required to give a talk on the development of this mill to our particular product.

I think you all will fully understand that the output of hot rolled sheets in England is very definitely limited, and that although the heavy cold rolling process is desirable from the point of view that it reduces the number of operations, we found it extremely difficult to convince ourselves, in the first place, that it would be possible to reduce a piece of hot rolled steel by cold rolling, to be of sufficient length without bagging, picture-framing, pinching, flopping, etc. on the four-high mill.

However, we eventually decided to go ahead, and we installed two mills, the distance apart of these two mills being arranged so that a third mill could be inserted between the two mills at present in operation. Between the two stands we arranged entry and exit conveyors. We commenced the process by breaking down 8-inch and 12-inch sheet bars, in 2-high hot mills.

We anticipated certain difficulties and chose high-class personnel for the breaking down of the bar and also insisted that the men on these hot mills should give particular attention to the shape.

We found, however, that although the hot product rolled was made to the best of the ability of the personnel on the hot mill, the resulting gauge uniformity was a matter which had to be very closely looked into after the initial starting.

Probably one of the most difficult points that was to be settled in connection with the actual operation was the control of roll contour on the cold mills. The point which gave us the greatest trouble was that it is impossible to keep the mills served from interval to interval at the same rate. The heat generated in the roll by the action of the cold rolling affected the roll contour. We, however, installed gas heating equipment on the work rolls of the 4-high mill so that the potential between the work rolls and the ambient temperature remained as nearly as possible at some fixed figure. We also tried many systems of cooling with liquids.

Another trouble we had was in connection with the carrying over of lubrication in the form of soluble oil, so that this soiled the surface of the cold-rolled product. However, we eventually managed to obtain compromises all around, which give a fairly satisfactory product now.

Association Activities

BIRMINGHAM DISTRICT SECTION
Monday, November 28

"MODERN TURBINES FOR STEEL PLANTS" by L. E. Newman, General Electric Company.

CHICAGO DISTRICT SECTION
Tuesday, November 1

"DIESELS IN THE STEEL INDUSTRY" by L. E. Caldwell, Electro Motive Corporation, La Grange, Illinois.

CLEVELAND DISTRICT SECTION
Monday, November 28

"PLANNED MAINTENANCE AND THE MAINTENANCE BUDGET" by E. C. Brandt, Westinghouse Electric & Mfg. Company, Pittsburgh, Pa.

DETROIT DISTRICT SECTION
Tuesday, November 15

"CONTRIBUTIONS OF ELECTRICITY TO STEEL INDUSTRY" by L. A. Umansky, General Electric Company, Schenectady, New York.

PHILADELPHIA DISTRICT SECTION
Saturday, November 5

"HEATING RATES OF STEEL FOR VARIOUS OPERATIONS" by A. J. Fisher, Bethlehem Steel Company, Sparrows Point, Maryland; Martin J. Conway, Lukens Steel Company, Coatesville, Pennsylvania; Fred J. Magis, Henry Disston and Sons, Inc., Philadelphia, Pennsylvania; T. A. Lewis, Bethlehem Steel Company, Bethlehem, Pennsylvania.

Use of MIXED GASES *for* STEEL MILL OPERATIONS

By E. T. W. BAILEY, Combustion Engineer

STEEL COMPANY OF CANADA, Ltd.

HAMILTON, ONTARIO, CANADA

Presented before the A. I. & S. E. Annual Convention, Cleveland, O., September 27, 28, 29, 30, 1938

▲ THE Dominion of Canada has very large coal resources which are to be found towards the extreme East and West sections of the country. The central provinces, in which are massed a large part of the country's industries, find it more economical to import coal from the nearest points in the United States. Even then they find the cost of coal is appreciably higher than it is for plants located nearer to coal mines. This fact makes it essential to direct the use of imported fuel in such a manner that the highest possible efficiencies may be obtained and waste eliminated wherever possible.

Following improvements in blast furnace stoves, blowing equipment and the use of coke braize for steam generation, it became apparent that the Steel Company of Canada, Limited, at its Hamilton Works, would have a substantial surplus of blast furnace gas available for general plant use, and in 1929 the Company completed the installation of facilities for supplying blast furnace gas to the various melting and reheating furnaces throughout the plant. Provisions were made whereby this fuel could be mixed with coke oven gas.

The author, E. T. W. Bailey, is combustion engineer at the Steel Company of Canada, Ltd.

BLAST FURNACE GAS DISTRIBUTION SYSTEM

The gas, on leaving the blast furnaces, passes through dust catchers and water spray towers from which a large portion is returned to the stoves and boilers. The remaining volume is conducted to the Theisen disintegrators where the gas is further cleaned and delivered to a gas holder of one million cubic feet capacity. The holder is built so that, no matter what lift is raised or dropped, the pressure remains constant. This is accomplished by weighting the top or inside lift with pig iron until the gas pressure of 20 inches of water is attained. The two outside lifts are counterweighted so that as they are raised or dropped, no change in pressure takes place. The holder thus serves as a pressure regulator and also provides sufficient reserve capacity to:

(a) Enable departments to cease or reduce consumption of the gas in an emergency and still keep the mains safely under pressure.

(b) Take care of short delays, such as tuyere changes, when only one blast furnace is in operation.

From the holder the gas is fed to the consuming de-

partments through nearly 5,000 feet of distribution mains made of riveted steel pipe, five feet in diameter, supported on steel towers 35-40 feet above ground. A walkway on top of the mains facilitates inspections. The mains are drained at suitable points so that the water precipitated from saturated gas can be removed.

The introduction of blast furnace gas as a plant fuel made it possible to shut down twenty-one gas producers.

COKE OVEN GAS DISTRIBUTION SYSTEM

The cleaned debenzolized gas is boosted to 5½ pounds per square inch pressure and delivered to the consuming points in mains—for the most part underground. Suitable reducing regulators are provided to adjust the pressure required at each point of consumption, whether the coke oven gas is mixed with blast furnace gas or used by itself.

By means of these systems, the two gases can be mixed in any desired proportion at any mixing station to suit local requirements.

The coke oven gas system is augmented further by a pipe line which delivers sufficient blast furnace gas to the suction side of the coke oven gas booster in order to enable 10 per cent by volume to be added. This expedient has only been used during periods of acute coke oven gas shortage, when requirements for this fuel made the supply inadequate for all furnaces operating at peak production rates.

The introduction of blast furnace gas into the coke oven gas does not seem to require that the total Btu. represented by the coke oven gas shortage, be made up by an equivalent number of Btu. in blast furnace gas. For example, a shortage of 500,000 cubic feet of coke oven gas was replaced by approximately 1,000,000 cubic feet of blast furnace gas per day and all units operated on the leaner gas without any serious curtailment of production. The success that attended this scheme apparently indicates that savings can be made in many locations by supplying a leaner gas. Further, this bears out the contention of others that the heating value of a gas can be manipulated within fairly substantial ranges without serious effects on operations. Some reasons for this will be indicated in charts shown later.

AUTOMATIC CONTROLS

The scope of this paper does not allow a detailed discussion of automatic controls. Nevertheless, they cannot be divorced from a mixed gas system which is largely dependent on automatic control. It is gratifying to note the improvements made in these devices during the last ten years and the Company has taken advantage of this by replacing some of the older designs by those of recent manufacture. All the large consuming points are metered while duplicate instruments record the flows at a central panel.

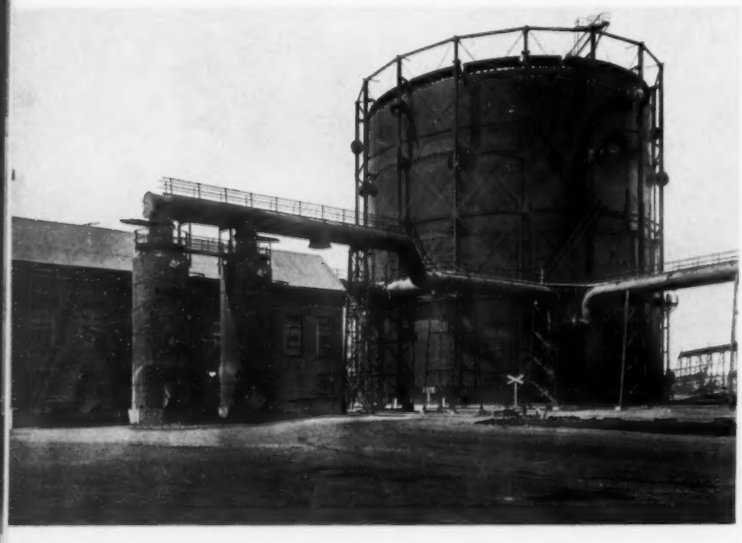
The controls for gas mixing stations operate on the volumetric ratio principle using orifice plates as primary measuring elements. It is not considered necessary to hold the Btu. value of leaner gases to a very narrow limit as some fluctuation in heating value does not seem to affect operations.

The tabulation (Figure 3) sets forth some of the more important relationships for representative natural, coke oven, blast furnace, and a 1:1 mixture of coke oven and blast furnace gases. The following items are of special interest:

No. 6 The air requirements for equal heat input.

No. 10 The Btu. per cubic foot in products of combustion furnishes the truest indication of the heating value of the fuel as the product gases are the media from which heat is transferred to the stock. It is interesting to note that a mixture of 70 per cent coke oven gas and 30 per cent blast furnace gas results in the same Btu. per

Theisen gas washers in the above building clean blast furnace gas, which then passes through separators and into a constant pressure gas holder.



Blast furnace gas and coke gas are piped separately to several mixing stations in the steel plant.

cubic foot of products of combustion as natural gas.

No. 12 When dealing with heat loss in products of combustion and its recovery by recuperation or regeneration, the volume of products for equal heat input is of importance. Of course, other factors such as gas composition are also important, but the volume thus indicated and further expressed in item No. 13 sets forth the fact that the volume of products from blast furnace gas is 68 per cent greater than that for an equal heat input in the case of coke oven gas.

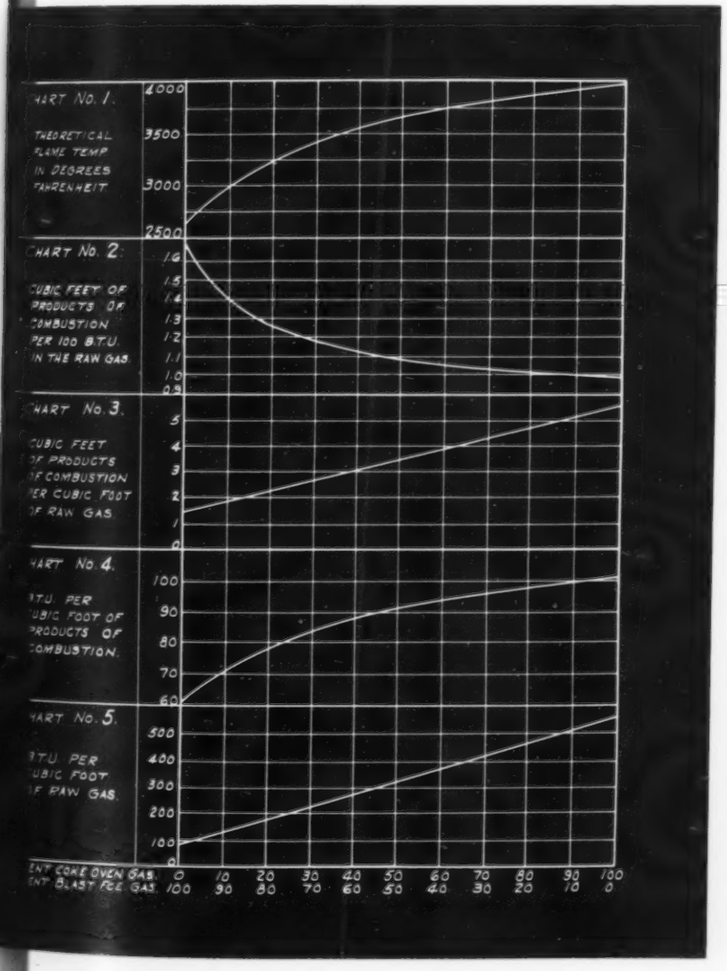
No. 14 and 15 These items indicate the importance of accurate air control for maximum efficiency when using the higher Btu. gases.

No. 18 and 19 When carbon monoxide in the products is held to an equivalent figure the losses are probably greater than indicated in the case of luminous flames from the high Btu. gases leaving a furnace—even allowing for the greater volume of products—where unburnt carbon particles carry away considerably more undeveloped heat than in the case of non-luminous carbon monoxide flames from the lower Btu. mixed gases.

Figure 4 contains five charts all based on mixtures of coke oven and blast furnace gas in percent by volume. All Btu. values are on the gross basis.

Chart No. 1 shows the theoretical flame temperature for various mixtures. The actual flame temperatures

Characteristics of various mixtures of blast furnace gas and coke gas. All Btu. values are gross.



Tabular comparison of characteristics of various gases.

No.	Item	Natural Gas	Coke Oven Gas	Blast Furnace Gas	1:1 Mixed Gas
1	Btu. per cu. ft. gas	1122	572	92	333
2	Specific gravity	.631	.438	1.02	.731
3	Cu.ft. products per cu.ft. gas	11.66	5.69	1.54	3.62
4	Cu.ft. air per cu.ft. gas	10.37	4.95	0.68	2.82
5	Cu.ft. air-gas mix per cu.ft. gas	11.57	5.95	1.68	3.82
6	Cu.ft. air per 100 Btu. in gas	.942	.866	.739	.847
7	Ratio of Btu.—B.F. gas = 1	12.20	6.22	1.00	3.62
8	Btu. per cu.ft. air-gas mix	97.0	96.1	54.8	87.2
9	Ratio of Btu. in air-gas mix —B.F. gas = 1	1.77	1.75	1.00	1.59
10	Btu. per cu.ft. products of combustion	96.2	100.5	59.8	92.0
11	Cu.ft. products per cu.ft. air-gas mix	1.008	.956	.915	.948
12	Cu.ft. products per 100 Btu. in gas	1.039	.995	1.672	1.090
13	Volume of products for equal heat input coke oven gas = 100	104.4	100.0	168.2	109.5
14	Percent carbon monoxide with 10% air deficiency	4.07	3.95	1.84	3.50
15	Btu. loss per cu.ft. gas—10% air deficiency	141.7	67.4	8.7	38.4
16	Btu. loss as percent of Btu. in gas—10% air deficiency	12.65	11.78	9.46	11.53
17	Percent air deficiency to give 6% carbon monoxide in products	14.3	14.6	26.9	16.3
18	Btu. loss per cu.ft. gas to give 6% carbon monoxide in products	205.8	91.8	24.8	62.5
19	Btu. loss as percent of Btu. in gas when 6% carbon monoxide in products	18.34	16.04	27.00	18.77
20	Cu.ft. gas equivalent to 1 million Btu.	891	1748	10870	3003

All Btu. are gross.

will be considerably lower, of course, but will have the same characteristics.

Chart No. 2 shows the cubic feet of products per 100 Btu. in the raw gas and illustrates an important relationship. A rapid reduction in the volume of products per unit of heat input results from small additions of coke oven gas. Indications are given whereby mixtures may be chosen to fit existing recuperators or regenerators in order to make the most of their capacity for heat transfer.

For a mixture of 90 per cent blast furnace gas and 10 per cent coke oven gas, the volume of products per 100 Btu. is reduced 16.7 per cent from that of straight blast furnace gas; while for a mixture of 90 per cent coke oven gas and 10 per cent blast furnace gas, the volume of products per 100 Btu. in increased only 1 per cent from that of straight coke oven gas.

Chart No. 3 shows the cubic feet of products of combustion per cubic foot of raw gas, which volume varies in direct proportion to the mixture.

Chart No. 4 shows that the Btu. per cubic foot of products of combustion (which, as stated previously, is the best indication of the comparative heating value of the gases) does not vary in direct proportion to the mixture, but rises very quickly for small additions of coke oven gas to straight blast furnace gas, and falls very slowly for equivalent volume additions of blast furnace gas to straight coke oven gas. For example, in a mixture of 90 per cent blast furnace gas and 10 per cent coke oven gas, the Btu. per cubic foot of products of combustion is increased 17 per cent more than that for straight blast furnace gas; while in a mixture of 90 per cent of coke oven gas and 10 per cent blast furnace gas, the decrease is only 0.65 of one percent less than that of straight coke oven gas.

Chart No. 5 shows that the Btu. per cubic foot of raw gas varies in direct proportion to the mixture.

Information concerning the mixing of blast furnace and coke oven gas is condensed in part in these charts. Other interesting relationships such as specific gravity, combustion air, etc., can be plotted for additional details. As the charts are all on the same base, the relation between any two curves can be quickly determined. At first sight, one might not suspect the existence of such relationships, but, once determined, they may be turned to good advantage.

OPEN HEARTH FURNACES

Mixed gas has been used in several of these furnaces for over nine years. Of late, however, this has been discontinued for lack of sufficient gas. When in use, the gases are mixed in a mixing box and piped, cold, direct to the furnace ports. The proportion of each is adjusted by the heater as the heat progresses. On one furnace the roof temperature control reduces the coke oven gas and increases the blast furnace gas at such time as the roof temperature exceeds the allowable limit. High turbulence and velocity in the port are necessary to direct the flame to the surface of the bath. The flames are practically non-luminous. This practice has worked well and has been very satisfactory as to fuel consumption. The safety, simplicity and low first cost of the application leave little to be desired.

The brick consumption per ton of steel is low. Each gas has a gas-air ratio control which on these furnaces effected a saving of 500,000 Btu. per ton. This was determined from two duplicate furnaces. For over two years the furnace without control consistently averaged 500,000 Btu. per ton higher. When control was added, the results for both furnaces became almost identical over a considerable period of time.

The furnaces reverse in about six seconds and no fuel is lost by reason of reversals. Automatic reversal by time or temperature difference as well as furnace pressure regulation are in use.

The gross Btu. per gross ton of ingots for two furnaces over two years (1935-36) averaged 4,300,000. This included all gas that went into the furnaces for heating up as well as actual production. The average ratio of mixed gases was 1:1 or equivalent to 330 Btu. per cubic foot. During 1937-38, with blast furnace gas reduced to about 10 per cent by volume, on continuous operation, with no heating up gas and a greater percentage of hot metal, monthly Btu. per gross ton of ingots as low as 2,900,000 were consistently obtained on the new furnace started in June 1937.

The use of blast furnace gas and atomized bunker C fuel oil is at present being tried. If successful, it will enable all furnaces to be built for gas, while either oil and gas mixture, coke oven gas, or mixed coke oven and blast furnace gas can be used at will. The fogged oil is added to a large volume of blast furnace gas to increase the Btu. per cubic foot to the equivalent of coke oven gas.

At all times both checker chambers are used to preheat air only. The checkers have been in continuous service for over one year in the furnace built in the spring of 1937.

SOAKING PIT FURNACES

The soaking pits, perhaps, offer one of the best places in a steel plant for the use of mixed gas. Unfortunately, up to the present, as the whole supply of coke oven gas is needed to operate other mill furnaces, it has not been possible to operate the pits on mixed gas. At such times as there is some coke oven gas available, due to a mill not operating, the pits use this fuel and blast furnace gas released is used to make steam; in turn releasing coke braize to stock. It is desirable to transfer this duty of acting as a flywheel for the regulation of available fuels to some other department. If the fuel oil—blast furnace gas mixing is a success, the open hearths would then be the ideal place, as their operation is more continuous.

It has been evident on eight new pits of a recent design and equipped with complete temperature and combustion control that temperature distribution in the pit from top to bottom is much more uniform with blast furnace gas than with coke oven gas. However, blast furnace gas has 68 per cent greater volume of products of combustion for equal heat input. The heat carried away in this volume of products cannot all be recovered by the combustion air passing through the recuperators and a considerable portion of the products has to be by-passed. If reference is made to

Figure 4, Chart No. 2, it will be seen that comparatively small additions of coke oven gas to blast furnace gas, very rapidly reduce this product volume per unit of heat input and there should be an economical mixture where the by-pass could be closed and the best possible results derived from recuperation. The volume of products would be adjusted by mixing the gases to preheat most economically the volume of air required for combustion.

Many attempts have been made to force the heating of ingots. With high flame temperature fuels this results in overheating or washing the tops and leaving the butts relatively cold. One would not attempt to heat a whole block of steel to a uniform temperature by directing an oxy-atetylene flame on a quarter of the area, nor on the other hand, would one have much success in applying such high temperature flames to the whole area until a thermocouple in the centre showed 2250 degrees F. without injury to the surface. A greater part of the tonnage charged in soaking pits is already hot and if high flame temperature fuels are used, they must be tempered with an excess of air, which does not help scale formation; or a high deficiency of air, which is very wasteful of fuel. A mixture of coke oven and blast furnace gas seems to afford the best all round fuel application.

The time may come when the temperature controller will regulate the mixture of the gases, rather than the volume of a high flame temperature gas, up to a certain point and then control the volume only for the soaking period. This will do away with stratification from low flows of rich fuels and make less temperature differential between the top and bottom of the pit.

Possibly, results approximating this ideal may be achieved by scientifically choosing a constant gas mixture and by using proper throttling to reduce the fuel input to the ingots' capacity for heat absorption at the higher temperatures.

One soaking pit was equipped for a trial on mixed gas. The gases were supplied in separate pipe lines and combustion of both gases took place in the burner port. The recuperator by-pass was kept open. During a period when 10 per cent coke oven and 90 per cent blast furnace gas was used separately, the Btu. per net ton of the ingots was 988,000, with 87.7 per cent hot and black hot steel. During the test period with the same relative gas volumes burned together, 718,000 Btu. per net ton of ingots with 86.7 per cent hot and black hot steel was obtained. This test indicates that it is more economical to burn both gases together than it is to burn each separately, for the ratio of mix investigated.

SHEET MILL FURNACES

The sheet mill is the largest consumer of mixed gas in the plant. Due to changes and increases in the demand for gas in this department it has been necessary to curtail mixed gas applications at other furnaces.

With the advent of strip mills, the use of mixed gas in sheet mill furnaces may not be of as much interest as formerly. There are, however, still many places where similar light sections are heated to about the same temperatures.

One of the chief advantages of mixed gas appears in the reduction of concentration of sulphur compounds (where they are not removed from coke oven gas) which results in the preservation of alloy beams, chains and rolls composing furnace conveyor systems. Were it not for blast furnace gas it would have been necessary to have gone to considerable expense to remove sulphur from the coke oven gas before alloys could be extensively used.

The continuous pack and pair as well as the older sheet and pair furnaces use a mixture of 2:1 blast furnace to coke oven gas or 245 Btu. per cubic foot. The continuous furnaces are equipped with on-and-off temperature controllers and the carbon monoxide in the products of combustion varies between 2½ and 5 per cent depending on the position of the control valve. The flames are practically non-luminous and appear quite blue when leaving the doors. It does not seem possible to obtain very much luminosity from gases mixed in a ratio of 2:1 and only a short streak can be noticed at the burner ports. The loss in heat leaving such furnaces is possibly lower than that experienced from luminous flames, for reasons mentioned before. Good heating is obtained and the product has a minimum of scale. The gross Btu. per net ton on pack heating over a month runs 1,666,000, inclusive of week-end light-up requirements. The pair furnaces show 1,238,000 Btu. per net ton under similar circumstances.

Blue annealing furnaces, as well as converted sheet and pair furnaces, use the same gas mixture with good results.

The normalizing furnace, a small walking beam type, uses a 1:1 ratio of mixed gas or 330 Btu. per cubic foot.

Box annealing furnaces use a mixture of 10:1 blast furnace to coke oven gas or 130 Btu. per cubic foot. These furnaces were formerly fired with producer gas and have made a good showing on mixed gas with a reduction of 1,300,000 Btu. per net ton. The improvement made in cleanliness and working conditions is noteworthy.

Radiant tube annealing furnaces are taking the place of the box type furnaces and mixed gas in the ratio of 1:9 blast furnace to coke oven gas or 500 Btu. per cubic foot has been used with good results and an average Btu. consumption per net ton of 780,000 over a year was realized.

BILLET FURNACES

A two zone billet furnace used mixed gas for several years until replaced by fuel oil in the upper burners and coke oven gas in the lower burners. During mill delays for roll changes, or intervals between turns, straight blast furnace gas is used in the lower burners and the fuel turned off the upper burners. This allows temperatures to be held without danger of overheating or excessive scaling taking place. The combination works very well.

FUTURE USES AND GENERAL NOTES

Future extensions for the use of mixed gas, when made available in sufficient quantity, are indicated for firing coke ovens, soaking pits and billet heating furnaces. Possibilities are also promising for blast furnace

gas and fuel oil mixes as applications are developed.

For the larger continuous furnaces, satisfactory results might be obtained by zoning with different mixtures,—rich gas at the entry, medium at the center and lean at the exit zone. Continuous soaking pits and strip sheet annealers may some day be a reality and the zoning of such furnaces by applying different mixtures of coke oven and blast furnace gas would appear to be a logical step.

Great care must be exercised when blast furnace gas is made available throughout a plant. Operators must be warned of its dangers, and signs should be posted where it may lodge around furnaces, under roofs of low buildings or in basements and pits. Generaous sized hoods should be provided on furnaces discharging gases from the doors, and care taken to have buildings well ventilated.

Before large mains are put in service, they should be thoroughly purged and bleeders must be provided at the ends of the mains to bleed gas until the mixture contains no oxygen. Shorter pipe lines to furnaces can be steamed and the steam kept flowing with the gas until ignition has been established in the furnace. Coke oven gas pilots are useful in many places. As only 0.7 part of air is required for 1 part of blast furnace gas for complete combustion, it is apparent how easily an explosive mixture can occur.

Flow meters with a large number of range changes are desirable, in order to avoid disturbing large orifice plates.

There should be provided large hand holes to clean butterfly valves, and steam coils to heat them in winter. The mains are drained manually as seals are not safe.

Present indications are that in the future mixed gas will become a standard fuel in many plants. In the words of Mr. H. V. Flagg,—"Fortunate indeed are those plants which have coke plants and blast furnaces in balance with steel plants, and have had the vision and the means to install cleaning, mixing and distributing facilities so that practically the entire fuel supply comes into the coke plant as coal".

DISCUSSION

PRESENTED BY

G. M. COUGHLIN, Combustion Engineer, American Rolling Mill Company, Ashland, Kentucky.

F. E. LEAHY, Fuel Engineer, Youngstown Sheet & Tube Company, Youngstown, Ohio.

P. F. KINYOUN, Combustion Engineer, Bethlehem Steel Company, Lackawanna, New York.

H. V. FLAGG, Combustion Engineer, American Rolling Mill Company, Middletown, Ohio.

J. H. BUCKHOLZ, Engineer, American Steel & Wire Company, Cleveland, Ohio.

R. I. GUMAER, Combustion Engineer, Jones & Laughlin Steel Corporation, Aliquippa, Pennsylvania.

E. C. MCDONALD, Combustion Engineer, Republic Steel Corporation, Cleveland, Ohio.

M. J. CONWAY, Fuel Engineer, Lukens Steel Company, Coatesville, Pennsylvania.

A. J. FISHER, Fuel Engineer, Bethlehem Steel Company, Sparrows Point, Maryland.

P. M. OFFILL, Vice-President, Amsler-Morton Company, Pittsburgh, Pennsylvania.

E. T. W. BAILEY, Conbustion Engineer, Steel Company of Canada, Ltd., Hamilton, Ontario, Canada.

G. M. COUGHLIN: Mr. Bailey has just preached a sermon which should be an inspiration to all fuel users in the steel industry. This story shows what can be done with fuel when its economical importance is given sufficient emphasis in presentation to management executives.

In these days of high operating cost, coupled with low selling prices and little, if any, profit, the engineer who can show plans which will reduce fuel costs 10 to 20 per cent is indeed a welcome visitor to the front office.

True, all of us do not have blast furnace gas to mix with coke oven gas and some of us are not fortunate enough to have even the coke oven gas available, but we all burn some gaseous fuel in our plants and therein lies room for action.

There is a hidden thought in Mr. Bailey's paper. It is not expressed outright but it can be read in nearly every paragraph. His fundamental principle is low Btu., coupled with high specific gravity, fuel gas. Let me repeat that. Use a low Btu. gas of high specific gravity.

That statement, qualified to meet the demands of individual applications, that is the sermon just preached by Mr. Bailey. The qualifications include among others, sufficient flame temperatures to do the required job, and considerations of the losses in waste products of combustion.

The first can be controlled either by the mixed fuel gas Btu. value or reclamation of heat from the waste gases or a combination of the two.

The second can be controlled by a mechanical application subject to the law of diminishing returns.

Rose, of Wisconsin Steel, showed in the late '20's, some things which could be done with blast furnace gas in the open hearth, when he mixed it with coke oven gas, and we have heard Mr. McKune, of the Hamilton plant just described in Mr. Bailey's paper, tell many times of the blast furnace gas-coke oven gas use in his open hearths. We have heard of this plant and that using such mixtures here and there and now we have a most excellent description of a complete plant fitted to use, and using with remarkable results, blast furnace and coke oven gas mixtures.

And those of us who are not among the chosen; those of us who are out of the fold; who are forced to

use the rich gases only, such as coke oven gas or natural gas, how are we to enter the pearly gates of low Btu. per ton shown so enticingly by Mr. Bailey?

What of recirculation of products of combustion by diluting our rich, high Btu., low specific gravity gases with those products of combustion. True we would not quite reach the gravities of the coke oven-blast furnace gas mixtures but we could approach them. Would we get comparable results?

The mechanical difficulties are easily solved. The natural gas people have been doing it on a small scale for years, merely to control the Btu. content.

What has been done along this line in an industrial fuel application?

Surely this question should be more fully investigated and could be made the subject of another very interesting paper for this society.

Mr. Bailey's paper is inspiring. The Btu. per ton figures he quotes set a high standard and he, and the operators with whom he is associated, are to be congratulated on the work they have done.

F. E. Leahy: The results obtained by introducing blast furnace gas into the main coke oven gas distribution system depends to a great extent on the types of furnaces using the mixed gas.

We have had some experience with mixing these gases in this way but we are limited by the flame temperature required for the welding furnaces. When this practice was first tried it was very interesting to us to discover how closely the welder's eyes were able to detect any changes made in the mixture.

A test was made, analyzing the mixture and checking the results against the change in flow of gases to the furnace, the change being made by the welder according to his requirements. We were surprised to learn how closely they followed any variation in the mixture with a corresponding change in the total flow of fuel to the furnace. As the load on a welding furnace is quite constant, the changes followed almost directly the variations in the gas mixing.

Successful welding operation was obtained down to 500 Btu. per cubic foot of gas mixture but with a decrease in rate of production.

In the welding furnaces the usual practice is to heat the skelp so that the edges are brought as quickly as possible to a fusing temperature without excessive softening of the center of the skelp. This is usually done with a sharp flame at the proper temperature which was difficult to get after the mixture of the gas had dropped below 500 Btu. per cubic foot. When the welding furnaces were not in operation, lower mixed gas temperatures of course could be and were used quite successfully in the balance of the furnaces.

In the description of the open hearth furnaces, some very interesting features are mentioned, such as roof temperature control by varying the mixture of the fuels, and the benefits derived from air/gas ratio control. The very excellent fuel rates obtained are an indication of good combustion control, furnace design, construction and operation.

In the description of the operation of the eight new soaking pits of recent design and equipped with combustion and temperature control, Mr. Bailey mentions that the temperature distribution in the pits from top to bottom is much more uniform with blast furnace gas than with coke oven gas. This would appear to be more characteristic to the design of pit rather than common to all soaking pits.

Soaking pits of the regenerative and circular type primarily fire into the butts of the ingots close to the bottom, while pits of various other types are fired in a different manner.

Mr. Bailey states that attempts have been made to force the heating of ingots in these pits with high flame temperature fuel which resulted in overheating and washing the tops and leaving the butts relatively cold. This condition I believe is not characteristic of all types of pits as the above-mentioned type of pits have been successfully operated heating hot or cold steel with either coke oven or natural gas or liquid fuel without any appearance of overheating when the pits are forced; and, in addition, with close control of the scale formation through ideal furnace atmosphere regulation. In fact, the quality of heating in these pits remains constant irrespective of the fuel used. The regenerative type of pits accomplish this through frequent reversals and the circular type of pit accomplishes this through utilizing the recirculation of the waste gases in the pit to modify the temperature of the freshly burned gases to the proper temperature for heating the steel at the maximum rate at which the steel is able to absorb the heat without damage.

Due to the design of some soaking pits, there is no doubt that proper operation can only be obtained by modifying the fuel. Where this is possible, the practice is no doubt very necessary in order to obtain satisfactory operation, but such designs limit the application to locations where the fuel can be obtained which is suited to the pit operation. However, it is possible to get a pit so designed that any fuels can be used as are available with no handicap to the operation.

I agree very strongly with Mr. Bailey that resorting to either the use of excess air or a high deficiency of air in order to secure satisfactory heating practice is a very undesirable method of accomplishing the results.

It is when heating cold ingots at a high rate that the real test is placed on the pit design. The demand is for a uniformly heated ingot with maximum yield without injury to the ingots being heated and to do this a variable control of the rate of recirculation of the waste gases is the proper mechanism for the transfer of heat.

In all plants the problem is to meet the demand for the most efficient utilization of the fuels available without waste and this requires careful planning in order that existing equipment will not be handicapped in producing either required quality at the maximum rate of heating. This means that when the supply of mixed gas is deficient that we are prepared to quickly substitute a mixture of natural, blast furnace gas, or liquid fuel. As in our plants we do not have any gas holders other than small ones at the coke plant for regulation, we must be at all times prepared to meet the variations in demands by adjusting the fuels as the demand varies. In one of our plants in the general mixed gas system is used either natural, coke oven, or refinery still gas. To the natural and refinery still gas is proportioned the proper amount of air so that the mixture will give a constant Btu. input with

a fixed pressure condition irrespective of the fuels being used.

P. F. KINYOUN: Mr. Bailey has very ably presented a description of the application of mixed gases in the modern steel plant and has also given valuable data on the relative characteristics of various gases. When available, I would like to know more about the results being obtained when using blast furnace gas fogged with Bunker "C" fuel oil. This scheme appears to offer an economical way of utilizing surplus blast furnace gas after a plant's supply of coke oven gas for mixing has been exhausted.

In order that the use of blast furnace gas in a steel plant will return the most profit, there are certain fundamental points that must be carefully analyzed. The first requirement that must be satisfied in the use of this gas is the heating of the blast furnace hot stoves. The fuel required for this purpose, assuming modern stoves fired with clean gas, is approximately 20-23 per cent of the total gas produced by a furnace or group of furnaces. After allocating the required amount of gas to heat the hot stoves, the next gas requirement is for blowing the furnace. This blowing can be accomplished by the use of gas engine driven blowers or turbo-blowers. The selection of this blowing equipment depends largely on furnace size, plant process steam requirements, and first cost of equipment. Whichever method of blowing is selected, approximately 15-20 per cent of the total gas produced should meet the requirements for this item. After satisfying the gas requirements for the hot stoves and blowing, there is available as surplus approximately 60 per cent of the total gas produced. For a blast furnace producing 1,000 gross tons of iron per day at an .80 fuel ratio, this surplus gas equals approximately 72,000,000 cu. ft. per day, or 3,000,000 cu. ft. per hour.

The important matter to now decide is to what use should the surplus gas be put. Should it be burned under boilers for the generation of steam for process and power generation; should it be converted into electric power, through the use of the gas engine driven generator; or, should it be utilized either alone or mixed with coke oven gas for firing metallurgical furnaces?

While the answer to these questions lies principally in the cost of the fuels or power for which the blast furnace gas can be substituted, its excellent suitability for metallurgical heating when mixed with coke oven gas should also be carefully weighed. I mean by this that even though fuel oil, for example, is relatively cheap as compared to the gas, preference should be given the gas fuel for heat operations, such as are carried on in soaking pits, normalizing furnaces and annealing furnaces. In other words, the quality of product as obtained when using gas fuel should be considered together with actual fuel cost.

If comparative fuel prices will permit, blast furnace gas mixed with coke oven gas for use in soaking pits, regenerative or recuperative reheating furnaces, normalizing furnaces, sheet furnaces and annealing furnaces makes an ideal fuel due to its controllability, relatively low flame temperature and large volume which contribute greatly to uniform heating of the product. When possible, it is preferred to carry out the gas mixing at the point where the gas is to be consumed. By so doing, local requirements of heating value per cubic foot can best be met, since these requirements are governed by furnace type, amount of air preheat available and type of heating required.

An important point in the application of blast furnace and coke oven gas in the steel plant is a sufficient flywheel to permit of some variance in supply and demand of the two gases.

In the case of coke oven gas, this essential feature can be taken care of, to a large extent, by its use in oil fired open hearth furnaces, when mill furnaces do not require it or by having one or two batteries of coke ovens arranged for underfiring with two fuels, one of them being coke oven gas. Good blast furnace gas flexibility usually can be provided by arranging steam boilers so that they are readily fired with two fuels, one of them being the blast furnace gas.

Mixed blast furnace and coke oven gas was first used at the Lackawanna Plant of the Bethlehem Steel Company eight years ago and at present is being utilized successfully at the following furnaces and soaking pits:

2—regenerative hearth bottom reheating furnaces at the rail mill.
24—regenerative soaking pit furnaces at the 44″ bloomer.
3—continuous reheating furnaces at the 24″ bar mill.
2—continuous furnaces at the 12″ bar mill.
1—reheating furnace at the 10″ bar mill.
4—hearth type regenerative furnaces at the 28″ structural mill.
2—continuous furnaces at the 14″ structural mill.
24—soaking pit furnaces at the 54″ bloomer.
1—150-ft. normalizing furnace at the continuous strip mill.
44—radiant tube annealing covers at the continuous strip mill.
3—3-zone slab furnaces at the continuous strip mill.

Mr. Bailey's paper emphasizes precautions which should be taken for the safe handling of blast furnace gas stressing warning signs and the purging and maintenance of positive pressure in mains. These are important points and should be carefully followed by anyone using this gas.

In those plants which are operated in conjunction with blast furnaces and coke ovens, the aim is to deliver coal to the coke ovens and carry out all subsequent heating operations without the purchase of additional fuel. Extensive use of mixed gas as outlined by Mr. Bailey assists in attaining as near as possible this goal.

H. V. FLAGG: How much variation in heat value do you get and what effect does it have on operation?

P. F. KINYOUN: When our need for coke oven gas reaches the point where the supply is too low we put in a little blast furnace gas. You can only go so far on that. We get down to about four hundred ninety to five hundred Bru. per cu. ft.

J. H. BUCKHOLZ: I would like to know whether Mr. Bailey has had any experience with mixing coke gas and natural gas. In order to utilize all the coke

gas in all our plants in the best practical manner we might possibly have to mix it with natural gas. I would like to know if he has had any experience in that line?

R. I. GUMAER: I would like to ask Mr. Bailey what cleanliness is desired in the blast furnace gas for these various metallurgical furnaces and soaking pits? It is obvious that too fine a degree of cleaning is a waste of money, and we are particularly interested in soaking pits. I feel that their cleanliness requirement wouldn't be as great as on other furnaces.

E. C. MCDONALD: When the blast furnace gas is distributed, no doubt Mr. Bailey has a very thorough accounting of that blast furnace gas, but how does that check up with the production of gas as worked out?

M. J. CONWAY: Mr. Bailey has presented us with a splendid paper on the use of mixed gases containing a lot of information that will be valuable to all of us who are fortunate enough to have gas available for distribution in the plant. By way of opening up discussion, I would like Mr. Bailey to tell us about the degree of cleanliness that he feels the gas should have leaving the Theisen disintegrator in order to keep away from valve and control troubles. I would also like to know what troubles, if any, they have experienced due to freezing of the moisture in the blast furnace gas line and what steps they have taken to prevent such trouble?

Also, if Mr. Bailey has experimented with low pressure oil burners using blast furnace gas instead of low pressure air as the atomizing media?

A. J. FISHER: We note Mr. Bailey's paper with considerable interest and agree with his practice and conclusions relative to uniform heat input to furnaces with a variable Btu. gas. However, there are only a few furnaces where this can be applied economically. They must be large furnaces in order to carry the added cost of more elaborate control and they must be close to the blast furnace and coke oven departments in order not to have a too elaborate and too costly gas distribution system.

At Sparrows Point we have three gas distribution systems with central mixing stations serving the steel plant as follows:

Place	Btu. per cu. ft.
Old soaking pits	100 to 300
New soaking pits	90 to 100
General plant	500

The Btu. of the gas at the soaking pits is changed from time to time depending on the heating rates desired. The richer gas gives a higher flame temperature and is consequently more effective on cold steel or when higher heating capacities are expected. All pits served by one mixing station operate on the same Btu. gas at the same time. There is no "sweetening 500 Btu. gas" on each pit; it being considered more economical to operate on the lower flame temperature mixtures which prevents excessive scaling and burning of the ingots. The lower Btu. gas is also outstandingly easier on the refractories of the pits which makes for lower rebuilding costs.

The general plant gas system is operated at very close limits to 500 Btu. There are a considerable number of furnaces in this system, both large and small. The uniformity of the gas in this system is most imperative because of the control set up on each furnace, and because of the special atmosphere gas machines and radiant tube furnaces operating in the annealing departments of different mills.

This system operated about ten years on 300 Btu. mixed gas with very good results and was changed to 500 Btu. in 1937 in order to get a higher Btu. capacity through the existing pipe lines and pumps.

Although the 500 Btu. gas contains about 400 grains of sulphur per 100 cu. ft. against the 200 grains of the 300 Btu. gas, no apparent adverse effect on the alloys in the various furnaces have been noted to date.

P. M. OFFILL: In my opinion, this excellent paper of Mr. Bailey's should be the first of a series to be read annually on this subject. Increasing use of mixed fuel gas presages the need for all available data.

Figure No. 4 of this paper can well be made a part of the combustion engineers' handbook and a good companion chart would show the effect of continuously high air preheat temperatures on theoretical and actual flame temperatures of various mixtures of lean or rich fuel.

Comparatively few plants are using mixed blast furnace and coke oven gas of 125 to 150 Btu. per cubic foot and there is much to be learned from actual operations on these mixtures.

The use of large proportions of blast furnace gas not only effect fuel economies but will also help to achieve higher quality of heating. This is important particularly for the reason that the manufacturers of steel demand a much higher quality of heating than heretofore. This has brought about the development of heating furnaces that are primarily designed for quality heating.

Undoubtedly the lean fuels are more desirable now that preheated air is available at temperatures up to 1900 degrees Fahr. with recuperators so built that they will maintain uniform preheat temperatures and with the elimination of practically all leakage. With air preheat consistently and constantly up to this temperature, it is much more simple to produce satisfactory results with lean fuels.

We would be interested in hearing further from Mr. Bailey on any developments on this subject since this paper was written and also his observations on the varied scale conditions when heating with rich or lean fuels.

E. T. W. BAILEY: Since the paper was prepared mixed gas has been used in the soaking pits for some two months and the results have been all that was expected. Top temperature limit controls have also been installed and it is quite interesting to see how these act on mixed gas. The top temperature limit control comes into action earlier in the heat when burning coke oven gas than when mixed gas is used. With the latter fuel the top thermocouple does not remain at the top limit (approximately 2500 degrees F.) for the extended period that it does on coke oven gas.

In connection with the addition of blast furnace gas to coke oven gas I certainly agree that there is a

(Please turn to page 70)

Continuous Pickling of WIDE STRIP STEEL with Flash WELDING

By L. R. MILBURN, Engineer

GREAT LAKES STEEL CORP.

ECORSE, MICHIGAN

Presented before the A. I. & S. E. Annual Convention, Cleveland, O. September 27, 28, 29, 30, 1938

▲ THE present-day wide strip mill has created a demand for longer coils of strip steel, both for the cold mill department and the fabricating plants. Since most of the present-day mills must cross-roll the slab to get the wide strip, the coil is of necessity rather short. The coils are so short, that it is costly to handle them in the cold mill due to the many setups to cold reduce a given tonnage. This paper will consider one of the methods for increasing the length of these coils, namely, by flash welding.

LOCATION AND ARRANGEMENT OF EQUIPMENT

At the Great Lakes Steel Plant we have installed three 96″ wide continuous pickling lines. Two of these lines are equipped with brick pickling tanks and the third line is equipped with rubber-lined steel tanks.

Figure 1 shows a plan of our continuous pickling department, which is located in the coil storage building.

Figure 2 shows a longitudinal section through continuous pickling line No. 3. This drawing will give some idea of the location of the apparatus.

We have installed a Mesta-Thomson-Gibb 96″ flash welder and flash trimmer in our continuous pickling lines Nos. 2 and 3.

We will discuss here the equipment located in line No. 3, as it was the first successfully operated wide strip 60 cycle flash welder with a Mesta plow type flash trimmer to be installed. This welder being one on which we have the most complete records and data at the present time, we will confine this paper to its description. Our second welder was installed during May, 1938.

It can be seen by referring to Figure 1 that this line consists of the following apparatus: Coil conveyor, coil upender, Mesta processor with coil opener, squaring device, upcut shear, flash welder, flash trimmer, stitcher, pinch roll, tables and guides. The balance of the line is equipped with standard accessories pertaining to a continuous pickling line.

You will note that we have located our stitcher between the flash trimmer and No. 1 pinch roll. This arrangement was made for two reasons; first, lack of room ahead of the welder and, secondly, we did not wish to pull the stitch through the flash welder owing to the limited clearance between the welding dies and the possibility of damage that might occur to these dies by the stitch scratching them. After we had developed proper tables, aprons, and guides, we experienced no difficulty with this arrangement.

DESCRIPTION OF EQUIPMENT

During the course of this paper,—where I seem to criticize the machinery, I do not want you to feel that the fault lies with the manufacturers or their designing engineers, as this is not the case. We are trying something new and in a new way; things were expected to go wrong. The equipment developed up to this time would not fit our conditions; therefore, we had to feel our way along. The machinery manufacturers worked with us 100 per cent to make a successful installation. We did develop a successful welding line, which is capable to operate efficiently and continuously.

We will now attempt to give you a description of the various pieces of equipment located in this line and used for joining the strips together for continuous pickling.

L. R. Milburn delivering the paper at the Annual Convention in Cleveland, Ohio.

PROCESSOR

The processor consists of a mandrel, breaker roll, pinch rolls and leveller. I can give you a description of how it works, better than I can describe the machine. The coil of steel to be processed is delivered from the upender to a motor-driven cradle. This cradle can be elevated and moved sideways to pass the coil onto the mandrel. The cradle can also be used to rotate the coil in order to start the strip into the pinch rolls. The mandrel is equipped with adjustable side guards to line up the coil for proper entry into the pinch rolls and thence into the leveller.

That the processor is actually breaking the scale is proved by the class of pickling we are getting on this line.

The processor proper is driven by a reversible 75/100 horsepower adjustable speed direct current motor. The breaker roll is raised and lowered by a direct current torque motor drawing power from a small 50 volt motor generator set. The cradle motions are all driven by 3 phase a-c squirrel cage induction type motors.

SQUARING DEVICE

This so-called squaring device is a misnomer, as it is in reality a bias cutting device. The end of the incoming strip must be cut on a bias in order to make a satisfactory weld. This is necessary in order that the two ends to be welded will touch only at one corner when the heating operation starts. Should the strips touch for the full width, they would not heat and consequently no weld could be made. The arc must start at one side and progress uniformly across the strip to make a satisfactory weld. To assure that this phenomenon will happen, we cut one strip end square and the other biased.

UPCUT SHEAR

The shear is a modified standard upcut shear. The modifications consist of the following: The shear is mounted on a moveable base to allow for adjustment sideways or across the line of the strip; also the shear knives are equipped with a set of auxiliary knives located at one end. These auxiliary knives set at right angles to the main knives or parallel to the strip.

These modifications were intended to be used to compensate for the variance in width of the front and tail ends of the coil strip to be welded. These modifications were never used for two reasons. One is that the wide end of the strip enters the welder first, and, since the notching knives were not located to notch this end, we were unable to use this feature. The second is that we have found it unnecessary so far to operate that way. However, the apparatus is there and by reversing the notching knives we could use it, if the necessity should arise. The shear is used for cropping and bias cutting only.

Figure 3 is a diagram showing the difference in widths between the front and tail ends of a coil. You will note that the tail end off the hot mill is wider than the front end. This tail end is the first to enter the welder. This sketch was made for the purpose of settling an argument and may be of some help to you men present.

WELDER

All motions of the welder are electrically driven, except the pull back of the moveable die, which is electrical controlled, air operated.

The push-up cam, which moves the movable die, is driven by a 25 horsepower, 230 volt, d-c., 650/1300 rpm., compound wound, mill type motor.

The gauge head is driven by a 15 hp., 725 rpm., d-c., mill type motor and the clamp motion is driven by a 25 hp., 650 rpm., mill type motor.

The side guards are driven by a-c. squirrel cage motors.

This welder will successfully weld strip of a maximum width of 96″ and a thickness of .125″. The minimum width handled so far on this machine was 32″ with gauges from .060″ to .115″.

One of the difficulties encountered on this machine was due to the thinner gauges of wide or medium wide strip. The flexibility of the thinner gauges makes it difficult to properly line up the strip ends in the welder dies.

Other difficulties experienced on the welder were caused by excess backlash in the couplings used to drive the shafts of the rotating cam limit switches. This caused false operations. We overcome this by replacing the couplings with a more rigid type. We had to replace some of the cam limit switch functions

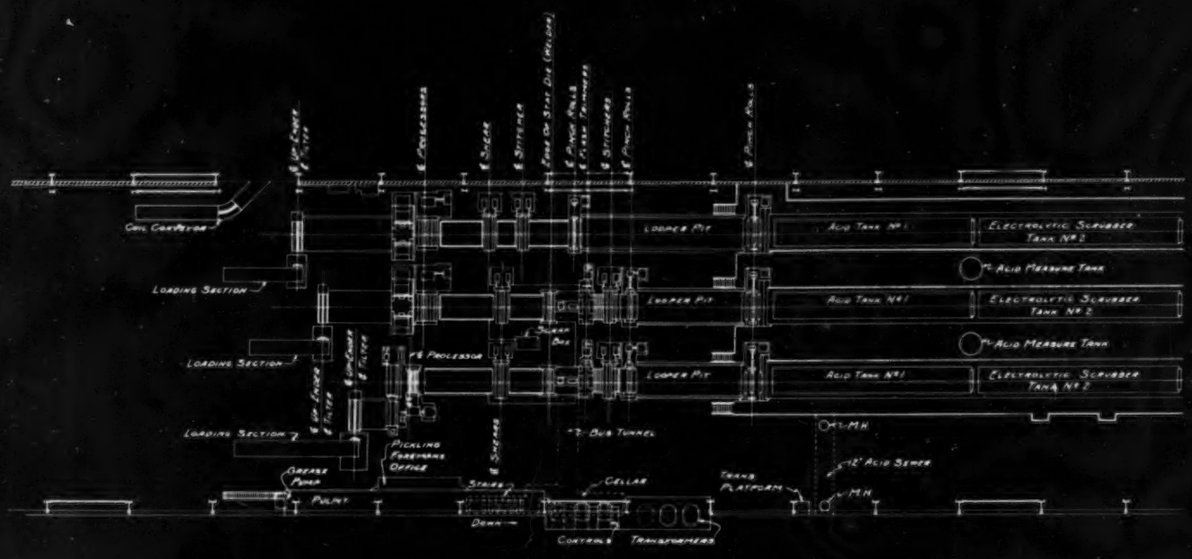


FIGURE 1—General plan view of the continuous pickling department of Great Lakes Steel Corporation.

with hatchway type switches and even went so far as to substitute a pushbutton where we needed extreme accuracy.

As an example, we installed a pushbutton to take the place of a hatchway limit switch on the pullback motion of the push-up drive in order to assure that the dies would be open to their extreme limit before the gauge head could pass down between the welding dies. We also had to modify the electrical control and add some precautionary wiring devices before we could obtain successful operation. Special lighting equipment had to be installed in order to reflect the under side of the strip in the mirror, which is located under the welder dies. This mirror and lighting are to assist the operator in aligning the strip for welding.

There are two welding auto transformers located in the stationary base of the welder. Power supply to these transformers will be taken up later in this paper under "Power". These transformers were arranged for watercooling. The cooling was found to be unnecessary on our installation, as the operation is not severe enough to overheat the transformers.

TRIMMER

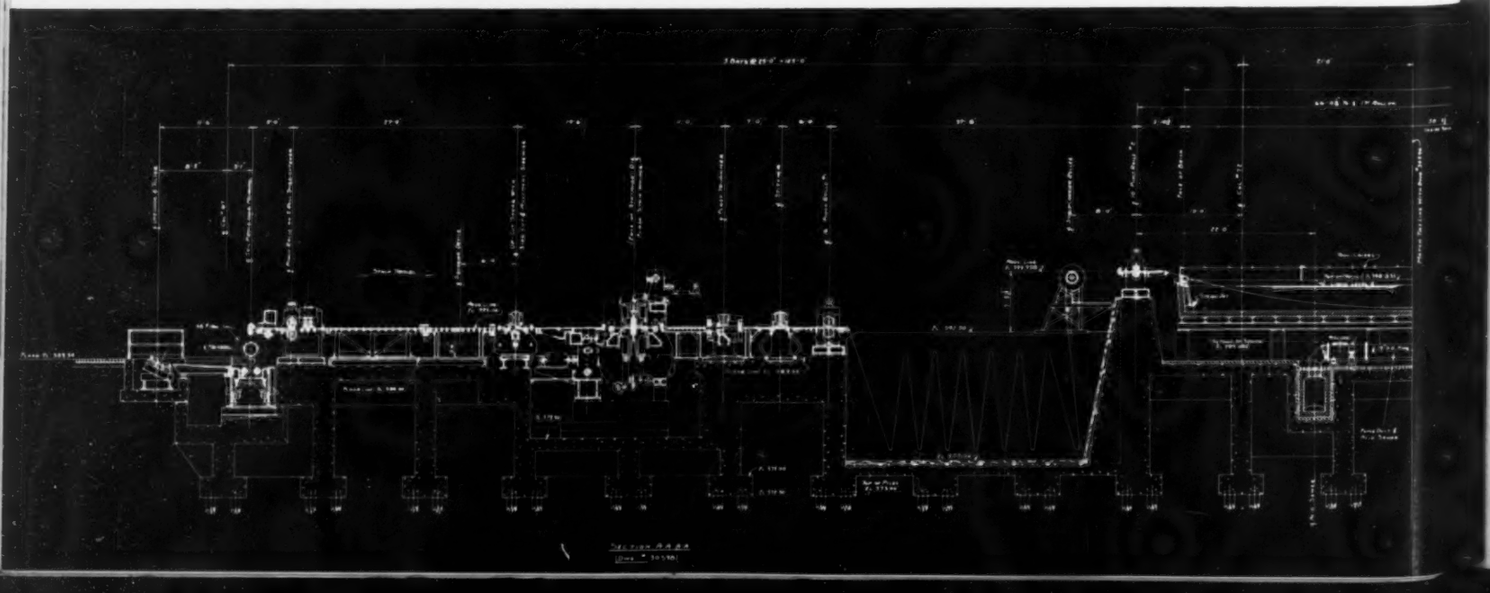
We did not contemplate the use of flash welding when we first projected our continuous pickling department. That being the case, we were unable to find sufficient clearance to install the conventional shaper type flash trimmer of such proportions as would be required to trim 96″ wide strip. A trimmer of this type would have required approximately 18 to 20 feet of floor space, half of which would have been out in the aisle; in fact it would have been projecting into the next pickling line, since our lines are spaced at 22′–6″ centers.

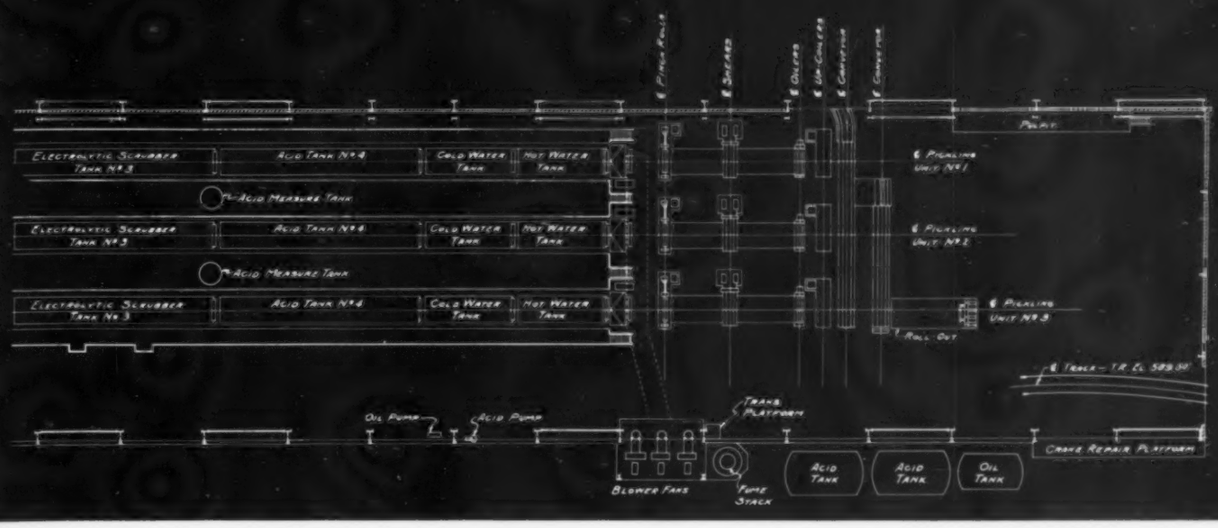
We, likewise, did not relish the idea of the time and patience required to set up the weld for proper trimming on the heretofore conventional flash trimmer.

Knowing our limitations and objections, Mesta Machine Company developed a radically different type of flash trimmer—a trimmer that should fit our available space and also a trimmer that would require less time to make a trim—thus speeding up the trimming operation. This resulted in the plow type trimmer, which has met both of these requirements.

This machine was designed to trim dry. We found that it would perform better if the strip was lubricated. We installed a motor-driven pump, a small sump, and some pipe with several nozzles to supply the lubricant to the top and bottom of the strip in front of the weld. We use a cutting compound known to the trade as "Kutwell No. 40" as a lubricant. Any cutting fluid should work, providing it does not contain oil. When the flash is removed we blow off the excess fluid and particles of flash with high-pressure air.

FIGURE 2—Longitudinal sectional view through the entry end of a continuous pickler.





The secret of trimming on this machine is a powerful pinch roll drive motor so as to give a steady slow pull of the strip through the trimmer. We have found that one set of trimmer knives will last from three to four months of steady operations, or equivalent to the processing of 100,000 or more tons of steel. All four edges of the knives are usable.

PINCH ROLL

Pinch roll No. 1 must have sufficient power to properly pull the strip through the trimmer. It should be equipped with a shunt wound magnetic brake to keep the strip from creeping while making the setup for welding. The motor driving this pinch roll must be built to withstand severe cycles of aceleration and deceleration. Our No. 1 pinch roll is driven by a 40/50 hp., 300/1200 rpm., adjustable speed, shunt wound motor.

It is important that the guides and aprons be properly designed. We found that experience and not theory was the determining factor in designing the guides and apron plates for our installation. With our arrangement of guides and apron plates between the various units comprising this equipment, our line functions smoothly and efficiently.

POWER

Now that you have a fair picture of the line itself, an attempt will be made to show how we powered the welder and, later in the course of this paper, how it works.

To supply power for the welder proper, there was installed a 3 phase, 60 cycle, 6600 volt, a-c. power line direct from No. 4 Substation (the substation feeding our No. 2 hot strip mill) to a transformer bank located under the auxiliary control panel pulpit (see drawing Figure 4). This transformer bank consists of two 1250 kva., 6600/440 volts, single phase, 60 cycle pyranol filled, self-cooled, power transformers. There is space left for the third transformer should it ever be required. These transformers were designed to withstand peaks of 3900 amperes on the 440 volt winding; they are wound with two 2½ per cent full load taps.

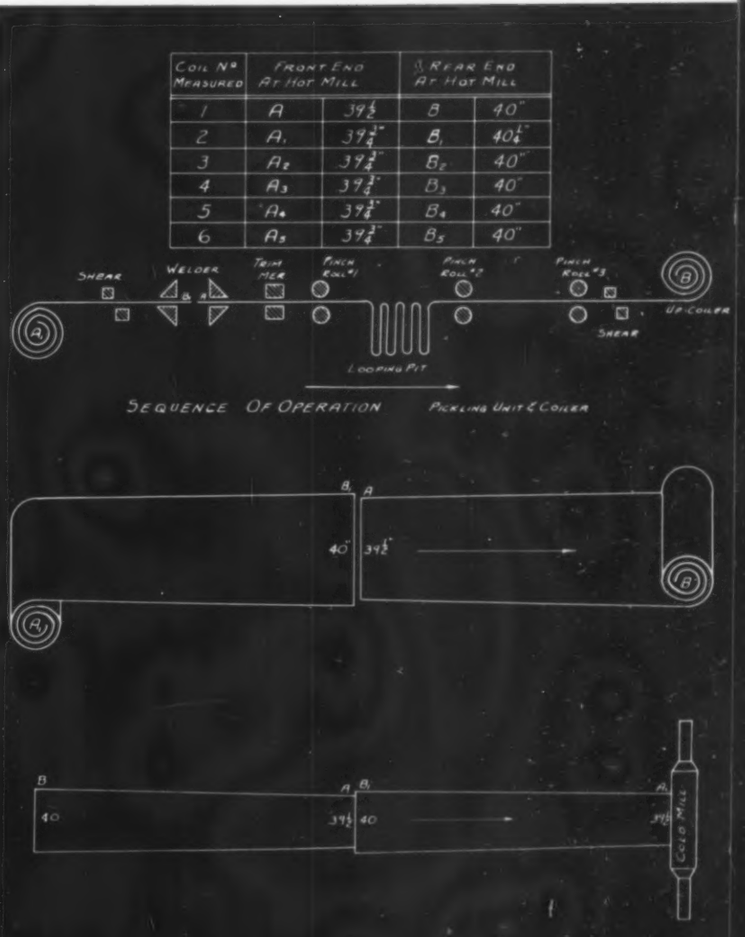
You might ask why a direct high voltage line was installed and why we chose a 1250 kva. transformer.

The answer to the first question is that our 440 volt auxiliary power feeder to the pickling department was overloaded and also our 440 volt auxiliary power transformer bank was so near fully loaded that we felt we could not safely put this additional load on it.

This proved a blessing in disguise, as we found that we had high voltage at the welder without voltage fluctuations. Voltage fluctuation has been the cause of much grief on other welding installations of which we know. The rating of the power transformer was an assumption. We had been advised that 1250 kilowatts would be required to make a weld. This was

FIGURE 3—Diagram showing the difference in widths between the front and back ends of coils.

Coil No Measured	Front End At Hot Mill		Rear End At Hot Mill	
1	A	39½"	B	40"
2	A_1	39⅝"	B_1	40⅛"
3	A_2	39¾"	B_2	40"
4	A_3	39⅞"	B_3	40"
5	A_4	39⅞"	B_4	40"
6	A_5	39¾"	B_5	40"



based on certain amperes per square inch of metal to be welded. There being no data available as to the power factor requirement of a welding machine, we assumed that a 1250 kva. transformer with high peak current capacity would do the work. We know now that our assumption was on the safe side.

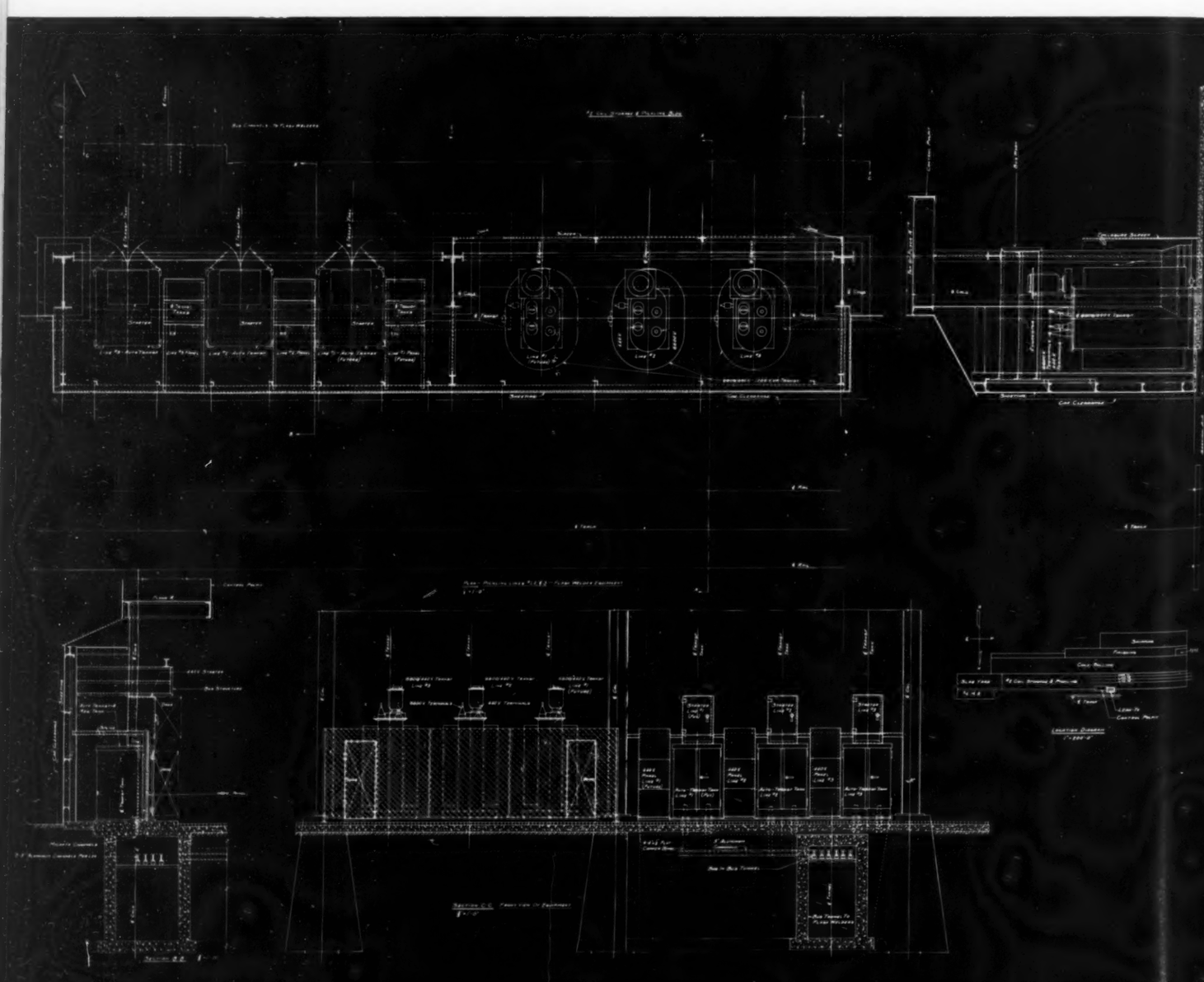
The 440 volt winding of each transformer is protected by a 4000 ampere, 600 volt, 2-pole, manually operated, trip free, overcurrent, protected, air circuit breaker. We use a 900 ampere, 2-pole, 600 volt, magnetically operated, high-speed welding contactor to apply and interrupt the welder current. We interrupt both sides of the welder circuit. The contactor is rated at 3600 amperes momentarily. This contactor is connected into the circuit between the air circuit breaker and the Thomson-Gibb multi-tap auto transformer. This equipment is located on the mill floor under a leanto adjacent to the main building. Two 5-inch aluminum channel conductors transmit the current from the multi-tap transformer to the welding auto transformers located in the base of the welding machine. Our object in placing all of this equipment on the main floor was first of all to make it accessible and next to avoid the congestion in the welder pit.

CONTROL

The entering end of the pickling line is controlled from two operating stands. Figure 5 shows the stand for the processor. Figure 6 is a photograph of the operating stand for the welder, and we are rather pleased with this stand. The operator can here perform all of the functions pertaining to welding, except move the side guards, and yet his vision is not obstructed by any projections. We have located additional pushbuttons on the shear, stitcher, and pinch roll to perform desired local functions.

This arrangement of the main control stand had as much to do with the successful operation of the line as any other one feature. This control stand was not perfect and some minor changes were made on the con-

FIGURE 4—Diagram showing the electrical equipment installed in conjunction with the flash welder.



trol stand for No. 2 welder as can be seen in photograph, Figure 7.

While we are on the subject of control, I would like to call attention to Figure 8—a conduit diagram of the welding installation,

OPERATIONS

Having attempted to give a description of the equipment and how it was supplied with power, we are now prepared to enter into the discussion of operations.

The primary object of the welder is to join two strips of steel so that they can be pickled, cold rolled and processed without having to cut out the joint. Heretofore continuous pickling of strip steel was accomplished by fastening two pieces of strip steel together by means of stitching, or some other method, which caused bulky joints, it being necessary to cut this joint out before cold rolling the steel, thus making it impossible to cold roll coils longer than the hot mill was able to produce from its maximum length of slab. This method was satisfactory and still is where the hot mill coils are of sufficient weight and length for economical cold mill operations. The development of the wide strip mill as adapted to our present steel mills has necessitated the rolling of wide strip in light weight, short coils. This is due to the length of slab that can be cross-rolled in the broadside mill stand.

Anyone familiar with cold rolling knows the difficulties encountered in entering the strip in the first stand of a tandem cold mill and the large amount of scrap resulting from our present-day operations with the conventional tension reel. So long as strip was comparatively narrow, this item was not so serious, but with the advent of wide cold strip mills the delay in entering the strip and the resultant scrap loss became factors of major importance. These two objections were, to a large extent, eliminated by the use of longer coils made possible by flash welding.

The first requirement in welding strip steel is to see that all of the mechanical equipment is properly adjusted and is functioning satisfactorily. Next we must determine what power will be required to make a satisfactory weld. The question is raised "What constitutes a satisfactory weld?". It is a weld that can be trimmed with ease—a weld that can be cold rolled and still show a Rockwell hardness somewhere near the parent metal.

The process of flash welding consists of heating by resistance, burning away the edges by flashing, then upsetting the metal while hot, thus forming a butt weld. The determination of the proper heat was found by trial, since all previous information given to us had been derived from 25 cycle current operations.

We suspected a "darkey in the wood pile" at the beginning of our experiments, and later we proved that "he" was the difference in heating value between the 60 cycle and 25 cycle current, the 60 cycle current being hotter for a given ampere welding load.

Our experiments consisted in making trial welds of various size sheets. The sheets were so selected that their cross-sectional areas would cover our entire range

FIGURE 5—(Below) Operators control stand for strip processer.

FIGURE 6—(Right) Operating stand for flash welder as originally installed.

FIGURE 7—(Lower right) Welder control stand of somewhat different construction.

of coil stock to be welded. The data obtained from these experiments was used to form the tabulation shown in Figure 9. Now that we had determined our heat chart, we were prepared to start welding operations.

At this time I wish to acknowledge the assistance of Mr. F. H. Speed, consulting engineer of the Thomson-Gibb Electric Welding Company, in compiling the data for this chart. (Figure 9.)

The tail end of strip A, cropped to full width and squared, is advanced through the welder dies. The gauge head is lowered down to clean the excess flash from the die faces and also to function as a gauge against which to butt or align the strip ends. This gauge is to form proper spacing for welding. Strip "B" is now advanced from the processor to the upcut shear. Here it is not only cropped, but is also cut at a predetermined bias. This is generally done in one operation, unless there is too much of a fish tail.

Ahead of the shear are located two adjustable side guards. These guards operate together and are driven

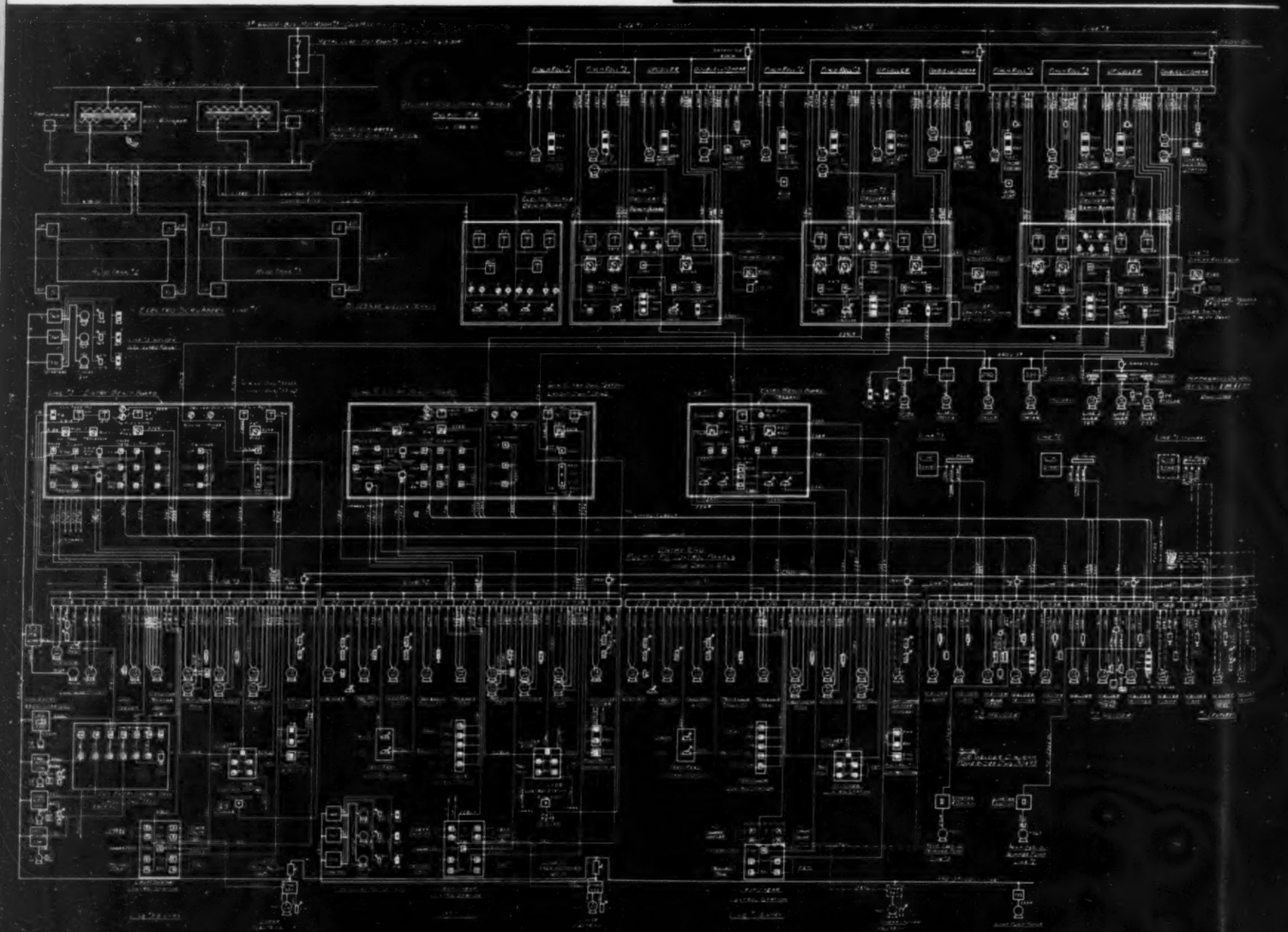
FIGURE 8—(Below) Diagram of conduit layout for the flash welder installation.

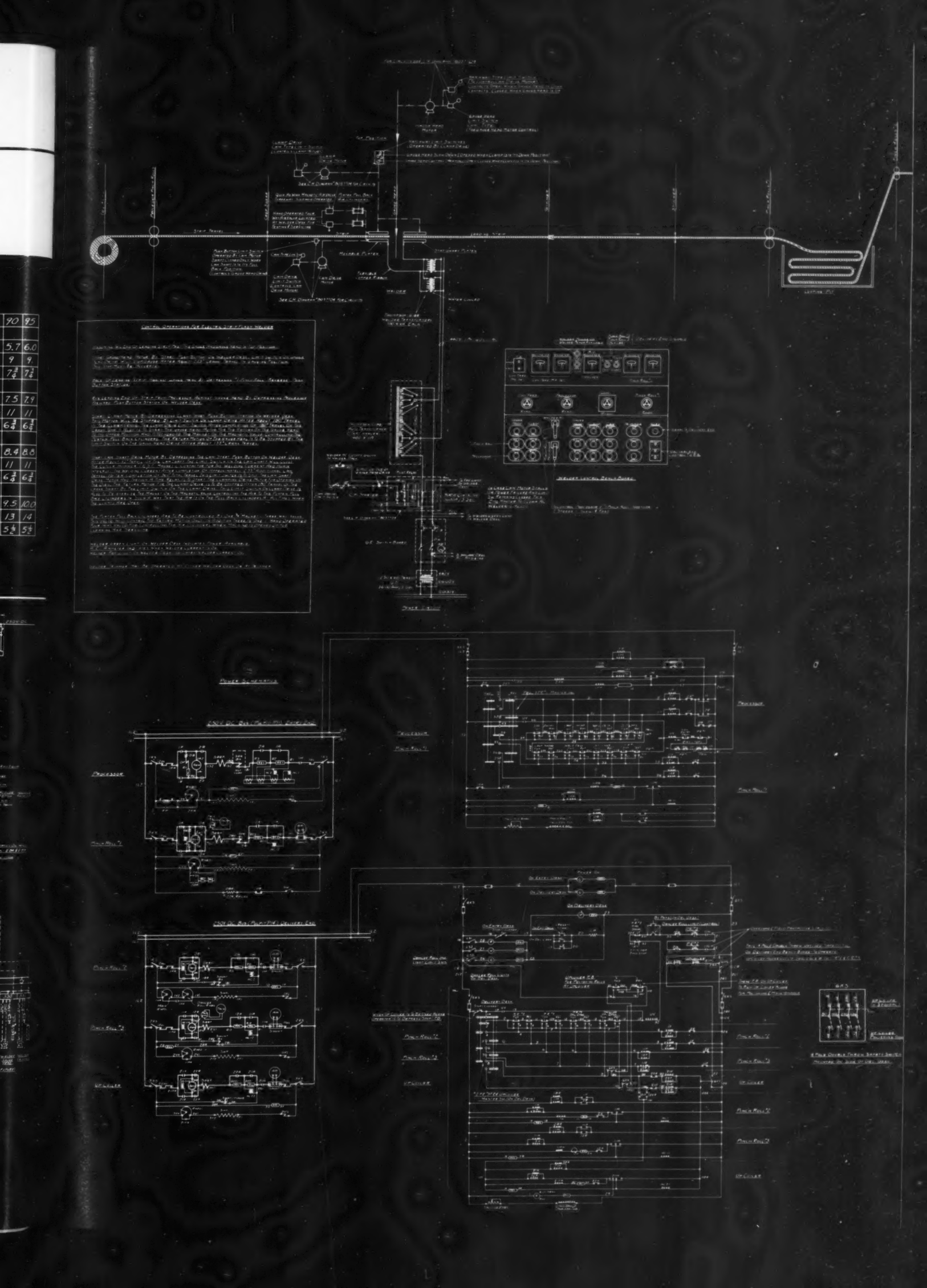
FIGURE 9—(Right) Tabulation of experimental data on 60 cycle power requirements for flash welding.

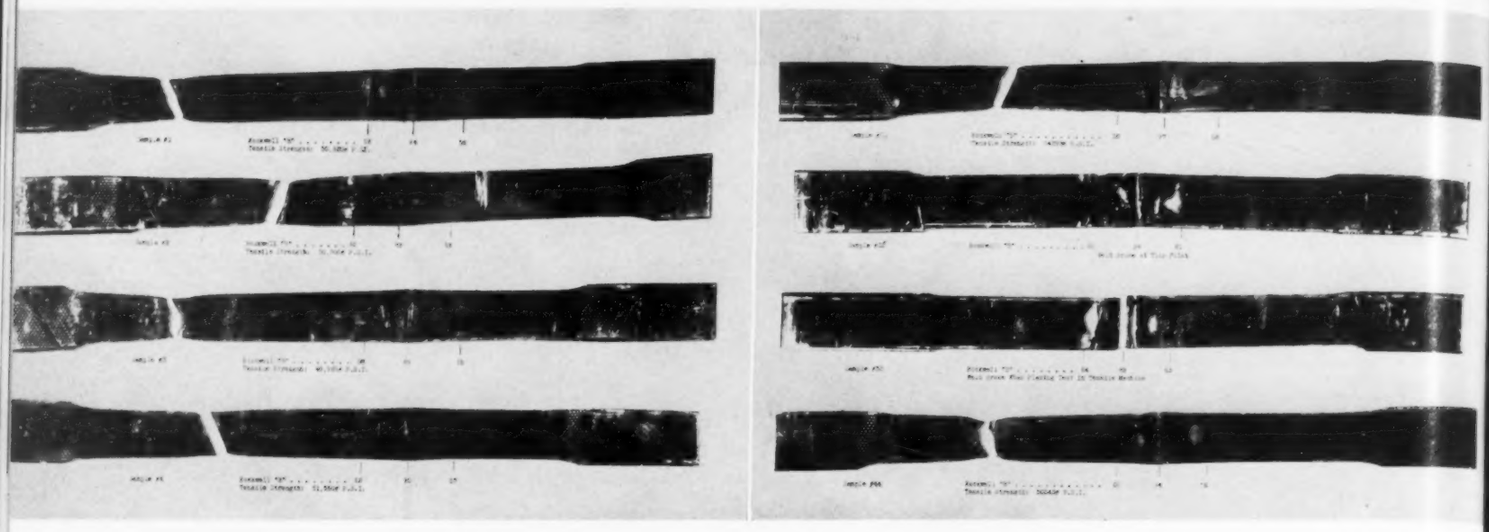
FIGURE 10—(Opposite page, top) Schematic diagram of controls for operating flash welder.

FIGURE 11—(Opposite page, bottom) Schematic diagram of power circuits of flash welder.

STRIP WIDTH—IN.	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
.063 GAUGE															
AREA-SQ. IN.	1.6	1.9	2.2	2.5	2.8	3.2	3.5	3.8	4.1	4.4	4.7	5.0	5.4	5.7	6.0
HEAT	7	8	8	8	8	8	8	8	9	9	9	9	9	9	9
CAM MOTOR RHEO	6½	6¾	7	7¼	7½	7½	7½	7¾	7¾	7¾	8	8	8	7¾	7¾
.083 GAUGE															
AREA-SQ. IN.	2.1	2.5	2.9	3.3	3.7	4.2	4.6	5.0	5.4	5.8	6.2	6.6	7.1	7.5	7.9
HEAT-	10	10	10	10	10	10	10	10	11	11	11	11	11	11	11
CAM MOTOR RHEO	5¾	5¾	6	6¼	6½	6½	6¾	6¾	6¾	6¾	6¾	6¾	6¾	6¾	6¾
.093 GAUGE															
AREA-SQ. IN.	2.3	2.8	3.2	3.7	4.2	4.6	5.1	5.6	6.1	6.5	7.0	7.4	7.9	8.4	8.8
HEAT	10	10	10	10	10	10	10	10	11	11	11	11	11	11	11
CAM MOTOR RHEO	5½	5¼	5½	5¾	6	6	6	6	6½	6½	6½	6½	6¾	6¾	6¾
.105 GAUGE															
AREA-SQ. IN.	2.6	3.2	3.7	4.2	4.7	5.3	5.8	6.3	6.8	7.4	7.9	8.4	8.9	9.5	10.0
HEAT	10	11	11	11	11	12	12	12	12	12	12	13	13	13	14
CAM MOTOR RHEO	5	5¼	5¼	5½	5½	5½	5½	5½	5½	5½	5½	5½	5½	5½	5½







FIGURES 12 AND 13—Samples of steel strip containing butt welds show tensile strengths of 48,860 to 54,295 lb. per sq. in., with Rockwell B hardness of 89 to 98 at the weld and 56 to 64 for the strip proper. It is to be noted that most of the samples broke outside of the weld.

by one motor. The two rear guards are set off center slightly so that, when all four guards clamp the strip, they will force the strip to take bias position on the table, as well as under the shear knife. The amount of this bias can be adjusted to any reasonable figure desired. We use one-quarter to five-sixteenths of an inch and are obtaining good results.

Strip "B" is then butted against the welder gauge head. The two strips must now be aligned carefully, both sideways and as to distance between the two ends. Motor-operated side guards are mounted, both front and rear of the welder, to assist the operator in the aligning operation. A mirror and spotlight are mounted beneath the welder dies to also assist the operator in properly arranging his strip ends for welding.

The ends of the strip being in proper alignment, the operator now sets the clamps to hold them in position until the weld has been completed. The setting of the

FIGURE 14—Transformers installed in connection with flash strip welder.

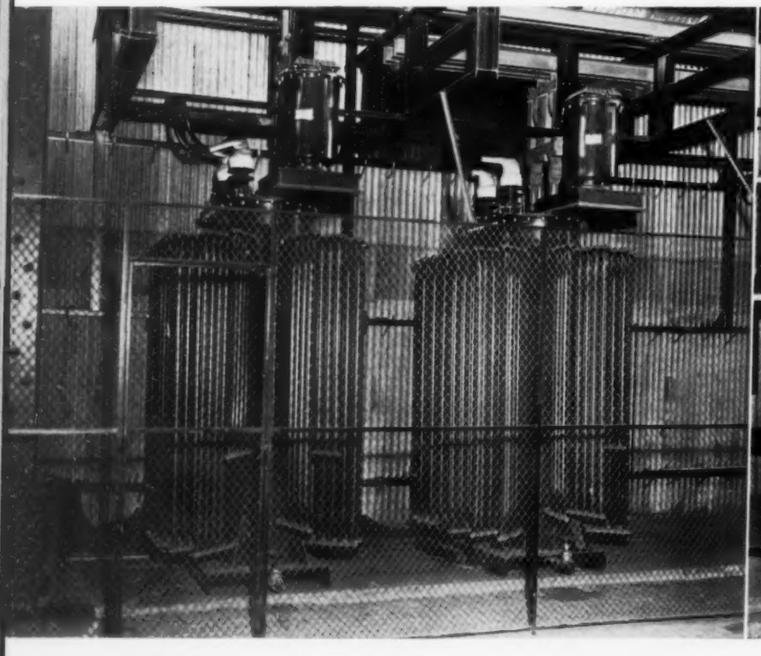


FIGURE 15—Switchgear for two flash welders installed in continuous pickling lines.

clamps will automatically cause the gauge head motor to lift the gauge clear of the weld and lock it in this position until such time as the operator lowers it again.

Having set the clamps and the gauge head being moved into the clear, the operator can now start the cam motion. This motion will energize the welder contactor, thus starting the welding current to flow in the strip across the gap between the two strips. Due to the bias cutting, the gap between the strip ends is like a trapezoid. The current will soon start an arc at the narrow end of this gap and thence progress across the width of the strip, thus producing the required heat for welding. The arc will also burn away the edges of the strip ends.

The time of burning is determined by the speed of the cam movement. The amount of burning is dependent on the current or the setting selected on the multi-tap transformer. This is all determined from the chart (Figure 9). The operator knowing the width and thickness of the strip to be welded can select the heat and speed required direct from Figure 9. This chart proved to be very accurate and another great help towards successful welding. The burning continues until the edges touch. At this point the current is automatically cut off and the cam drive upsets the hot metal to form the weld. The cam motion then returns to normal position without disturbing the welder dies. These dies remain in the closed position a fraction of a second to allow the weld to cool; then the clamps are released and the dies are opened by air. The weld is now complete and ready for trimming.

We move the weld along to the trimmer by means of No. 1 pinch roll. The strip is stopped with the weld a few inches from the point of the trimmer knives. Here we lubricate the strip and then set the knives in position to trim the bead. The trimmer knives do not touch the strip; in fact, they are set so as to leave a clearance of approximately .006″ between the knife and the strip. This clearance is adjustable. We have found that on heavy gauge strip we can set at .005″ and on lighter gauges about .007″ to .008″.

The knives having been brought into position, the strip is now pulled slowly through the trimmer by the pinch roll; the knives plow off the bead and leave a weld that can be cold rolled. The trimmed weld will now gauge from .010″ to .016″ thicker than the parent strip.

The secret of welding on this machine is soft welds. Soft welds can be obtained by close observation of the welding voltage. A voltage value of not less than 8 volts nor more than 14 volts should be used. Less than 8 volts will not furnish sufficient current to weld and voltages of over 14 will cause a hard or brittle weld.

We endeavor to hold our Rockwell hardness at not over 5 points above that of the strip. By frequent Rockwell and tension tests on sample welds, the machine can easily be kept in adjustment to make workable welds.

This welding installation was approved by our construction and engineering departments on October 8, 1937. It was put into production on October 10 of the same year and has worked successfully to date. We are averaging from 550,000 lbs. to 600,000 lbs. of finished steel per 8-hour turn.

The power required to make a weld is much less than we had anticipated. The kilowatt-hours per ton of steel pickled is approximately 3.5 kwh.

The current required at 440 volts to make a weld on 93″ wide by .105″ thick strip is approximately 700 amperes with a "push-up" peak of 1500 amperes. This current decreases as we weld strip of a lesser cross-sectional area. Example on strip 30″ wide by .060″ thick: The welding current is approximately 200 amperes and the "push-up" peak is around 1100 amperes.

CONCLUSIONS

We have proved that 60 cycle power acts different when welding than 25 cycle power.

We have proved that special attention must be given to the design of aprons, guides, and processing equipment.

We have proved that standardized welding equipment is not satisfactory. The transformers and auxiliary equipment should be tailor made for each installation.

We have proved that a good voltage supply is of vital necessity.

We have proved that welding in the continuous pickling line does not slow up operations as attested by the fact that our average time of setup, welding and trimming is from 70 to 90 seconds. A further proof of this is that our No. 3 Line will process the same amount of steel as either of the other two lines.

Our pickling department has developed the practice of welding three or more coils, then stitching one, depending on the weight of coils desired by the cold mill. This stitching is performed for the sole purpose of signifying to the upcoiler operator when to cut his delivered coils so that all coils of any order will be similar.

The installation of flash welder at our plant has been responsible for improvements in the rolling, handling, storage and processing of strip steel all along the line from the hot mill to the shipping departments. These welders have increased the efficiency of the cold mill processing department without additional cost to the pickling department.

The difficulties of welding strip from .060″ to .115″ thick, any width, were comparatively easy once we had developed proper heat curves and charts. Strip steel of less than .060″ thick is still a slow process due to the difficulty experienced in aligning the strip. This class of strip is too flexible to hold its shape at the gauge head for proper alignment.

The trimming operation has proved successful on all strips regardless of gauge. However, we do experience trouble on strip with a wavy or rippled center. These short ripples foul on the points of the trimmer knives and cause tears in the strip.

The points I wish to emphasize are:

1. Proper guides to control and assist the passage of strip through the equipment.
2. Good voltage regulation.
3. Correct heat and speed of push-up.
4. Correct welding voltage for the gauge of strip being welded.
5. The chemical analysis of the steel has little or no effect on the welding.
6. Careful attention to alignment of strip ends in the welder.

7. Careful maintenance of welder dies. See that they are kept clean and free from scale burns. Keep the edges of these dies sharp and square.
8. Keep welder free from electrical grounds.
9. Instruct your operating personnel carefully and thoroughly.
10. Keep trimmer knives sharp.
11. Do not trim too close. Find out what tolerance the cold mill department can stand and work accordingly.
12. Have the metallurgical department make frequent tests of sample welds to guide the pickling line foreman.
13. Last, but not least, when making an installation, do not attempt to perform all functions automatically, as the control will become too complicated. Endeavor to simplify the control all possible.

DISCUSSION

PRESENTED BY

H. W. NEBLETT, Engineer, Inland Steel Company, Indiana Harbor, Indiana.

A. L. MILTON, Engineer, Wheeling Steel Corporation, Yorkville Works, Yorkville, Ohio.

L. R. MILBURN, Electrical Engineer, Great Lakes Steel Corporation, Ecorse, Michigan.

E. E. SCHUKRAFT, Superintendent of Hoop Mills, Atlantic Steel Company, Atlanta, Georgia.

F. H. SPEED, Thomson-Gibb Electric Welding Company, Lynn, Massachusetts.

C. L. McGRANAHAN, Assistant General Superintendent, Jones & Laughlin Steel Corporation, Pittsburgh, Pennsylvania.

L. V. PONOMAREFF, Wheeling Steel Corporation, Yorkville, Ohio.

H. W. NEBLETT: Mr. Milburn's paper is a thorough discussion of a modern installation for welding and trimming flat strip steel. The development of this equipment is based on operating experience with electric flash welding equipment over a considerable period of time.

In the early part of 1935, Inland Steel Company began investigating the possibilities of welding hot rolled strip steel and in February of 1936 installed an electric flash welder for welding coils up to 72″ wide and .125″ thick. This equipment is still in service and doing very credible work on one of our three continuous pickling lines. The other two lines are equipped with welding equipment similar to that described by Mr. Milburn.

The electrical equipment for supplying and controlling the welding current is the same on both installations, but mechanically, the later welding units are greatly improved. The time required to weld and trim in a continuous pickling line is an important consideration. When our original installation was made, we hoped to perform this work in approximately 2½ minutes for each weld. After some experience had been gained with the equipment, this time was reduced to an average of two minutes. The later installations on our two remaining pickling lines involve equipment and mechanical changes that have improved the performance and further shortened the time required to weld and trim. We are now able to do this work in a maximum of 1½ minutes.

The mechanical changes involve wider and heavier welding dies. The clamping is changed from hydraulic to electric drive, thereby obtaining speedier operation and an effective means provided for removing the flash scale from the welding dies after each welding operation. The trimming equipment was changed to enable the upset to be removed from the weld without the necessity of spotting the weld in the trimming machine. The hotter the weld at the time the upset is trimmed, the less brittle the surface of the sheet at the point of weld.

All these, together with many other minor changes, have resulted in welding and trimming equipment that will perform this work in a period of time short enough to allow coils to be continuously fed through the pickle line and produce welds that will not break when being rolled in the tandem cold mills.

These two points are important. The weld must be made without having to stop the pickle line, and the weld must hold throughout subsequent processing The equipment as designed and installed will do that.

A. L. MILTON: We have a Mesta-Thomson-Gibb flash welder installed in our pickling line but it is designed for comparatively narrow strip (16″ to 40″ wide) used for cold rolling tin plate. Our practice is to weld only two coils together making one large, double coil (maximum weight 12,000 lb.) which, when rolled on our tandem cold mills, reduces considerably the lost time due to threading strip through mill, off-gauge plate, etc.

I may say that our welding practice differs, but slightly from that described in Mr. Milburn's paper.

Mr. Milburn speaks of shearing the strip on a "bias" amounting to ¼″ to 5/16″. We shear the strip "on the square" and obtain the correct amount of "bias" (1/16″) by using the equivalent of a tapered gauge head (the taper being 1/16″ in 42″). Mr. Milburn does not mention the use of a tapered gauge head, which we find to be of considerable value in aligning the ends of the strip.

I am submitting a print illustrating the operation of our welder. As will be noted in the diagram, the first part of the forward movement of the die, actuated by the cam, is a ½″ travel called the closing gap which brings the close edges of the strip ends together and starts the flash, the current having been automatically

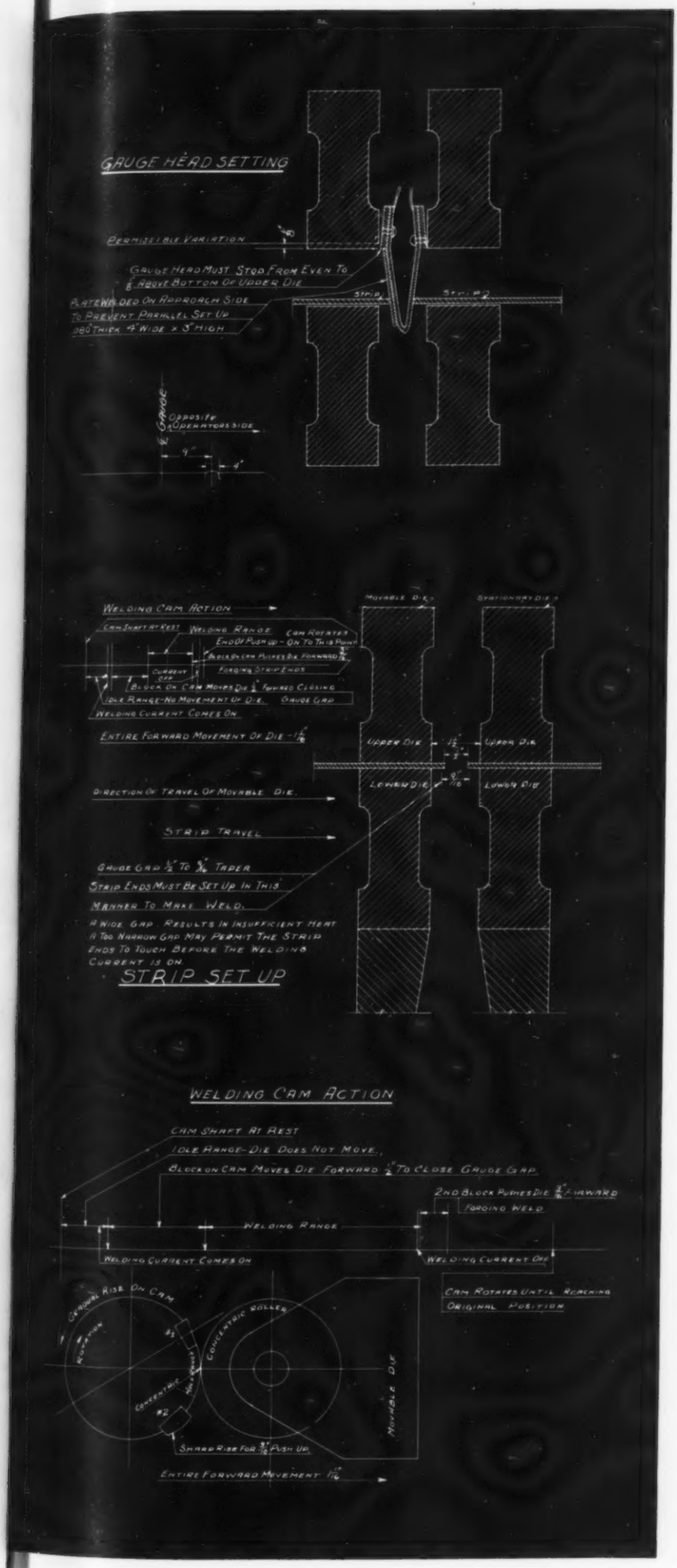

GAUGE HEAD SETTING
PERMISSIBLE VARIATION
GAUGE HEAD MUST STOP FROM EVEN TO 1/8 ABOVE BOTTOM OF UPPER DIE
STRIP
STRIP #2
ALTERNATE ON APPROACH SIDE TO PREVENT PARALLEL SET UP
.060 THICK 4" WIDE x 3" HIGH
OPPOSITE OPERATORS SIDE
WELDING CAM ACTION
CAM SHAFT AT REST
WELDING RANGE
CAM ROTATES
END OF PUSH UP - ON TO THIS POINT
RELEASES CAM PUSHES DIE FORWARD
FORGING STRIP ENDS
CURRENT OFF
BLOCK ON CAM MOVES DIE FORWARD CLOSING
IDLE RANGE-NO MOVEMENT OF DIE
GAUGE GAP
WELDING CURRENT COMES ON
ENTIRE FORWARD MOVEMENT OF DIE
MOVABLE DIE
STATIONARY DIE
UPPER DIE
LOWER DIE
DIRECTION OF TRAVEL OF MOVABLE DIE
STRIP TRAVEL
GAUGE GAP 1/2 TO 3/4 TAPER
STRIP ENDS MUST BE SET UP IN THIS MANNER TO MAKE WELD.
A WIDE GAP RESULTS IN INSUFFICIENT HEAT
A TOO NARROW GAP MAY PERMIT THE STRIP ENDS TO TOUCH BEFORE THE WELDING CURRENT IS ON
STRIP SET UP
WELDING CAM ACTION
CAM SHAFT AT REST
IDLE RANGE-DIE DOES NOT MOVE.
BLOCK ON CAM MOVES DIE FORWARD TO CLOSE GAUGE GAP
2ND BLOCK PUSHES DIE FORWARD
FORGING WELD
WELDING RANGE
WELDING CURRENT COMES ON
WELDING CURRENT OFF
GRADUAL RISE ON CAM
CAM ROTATES UNTIL REACHING ORIGINAL POSITION
CONCENTRIC ROLLER
MOVABLE DIE
SHARP RISE FOR PUSH UP
ENTIRE FORWARD MOVEMENT

Diagram illustrating action of flash welder at Wheeling Steel Corporation.

turned on during this first part of the cycle. After a slight hesitation, the second part of the cycle begins, consisting of a slow ½" travel called the flashing gap burning out the 1/16" V space left by the closing gap. The speed of this movement must be adjusted to the several cross-sectional areas of the strip. This adjustment is made by a rheostat in the shunt field of the cam motor. The third part of the cycle now begins. This is a rapid forward movement of 3/16" called the push-up, forging the strip together when approximately 3/5 of this push-up movement has taken place, the current is automatically turned off.

It might be of general interest if Mr. Milburn could give us the answers to the following questions:

1. What percentage of the welds pass through the cold reduction mills without breaking?
2. Is it the practice to slow down the mills or reduce the screw pressure while welds are passing through mills?
3. Do you believe that it would be advantageous to make the weld askew so the weld will pass through mill without a bump?

L. R. MILBURN: In answer to Mr. Milton's questions I would say 99 to 99.8 per cent of our welds go through the cold mill. All of them will go through if we watch our welding. We slow down the mill while the weld is going through to protect the strip from hanging on the side guides.

There is no advantage gained by welding askew; also the welding and shearing arrangement in the pickle line would be rather costly and require more floor space than we would have available. The scrap loss would be greater. By all means stick to right angle welding on wide strip.

E. E. SCHUKRAFT: I would like to know what is meant by processing. Is the weld allowed to get out to the customer?

F. H. SPEED: No. The strip is cut up, of course, into lengths and the coils are in different lengths. I know of a few cases when the material is used.

C. L. MCGRANAHAN: I could supplement that to some extent. There are certain jobs in which, due to various factors, it is not possible to give the customer as heavy weight coil as he wishes, in which case, if their chief inspector is agreeable, the weld is sent out. The weld, however, is not put into production. It is cut out and the blank is thrown away when it comes to the blanking press.

L. V. PONOMAREFF: It was mentioned that trimmer knives last from 100,000 to 140,000 gross tons of welded strip. Does that mean one edge of the knife or the life of the knives?

L. R. MILBURN: Not the life of the knife but the dulling of the four edges; after which it can be reground and used over again.

AMERICAN and EUROPEAN *Lubrication Practice* for STEEL MILLS

By R. M. GORDON, Manager

GORDON LUBRICATORS Division of

BLAW-KNOX COMPANY

Presented before the A. I. & S. E. Thirty-fourth Annual Convention, Cleveland, Ohio, September 27, 28, 29, 30, 1938

▲ THIS is obviously a subject about which volumes could be, and as a matter of fact, have been written, and it is therefore necessary, for the purposes of this discussion, to attempt to touch on only the relatively few points connected with the whole subject which, I hope, will be of the greatest interest to this group. The part pertaining to European practice concerns British mills only, and was gathered in a relatively short personal study of the major producing companies in England and Wales.

R. M. Gordon, the author, pictured entering the meeting room.

The proper lubrication of steel mill equipment is one of the most vital operations that the industry has to consider. Proper lubrication means two things: first, selection of the kind and grade of lubricant applicable to each problem, and second, its proper application. It is only in recent years that the science of lubrication has been accorded any serious thought by the industry as a whole. This neglect has been serious and far-reaching in its effects, and until such time as the designers of mill equipment, and the chief engineers of the operating companies sit down and intelligently apply themselves to the problem, the steel industry as a whole will continue to suffer from needless waste, resulting from over, under, and poorly-designed lubrication.

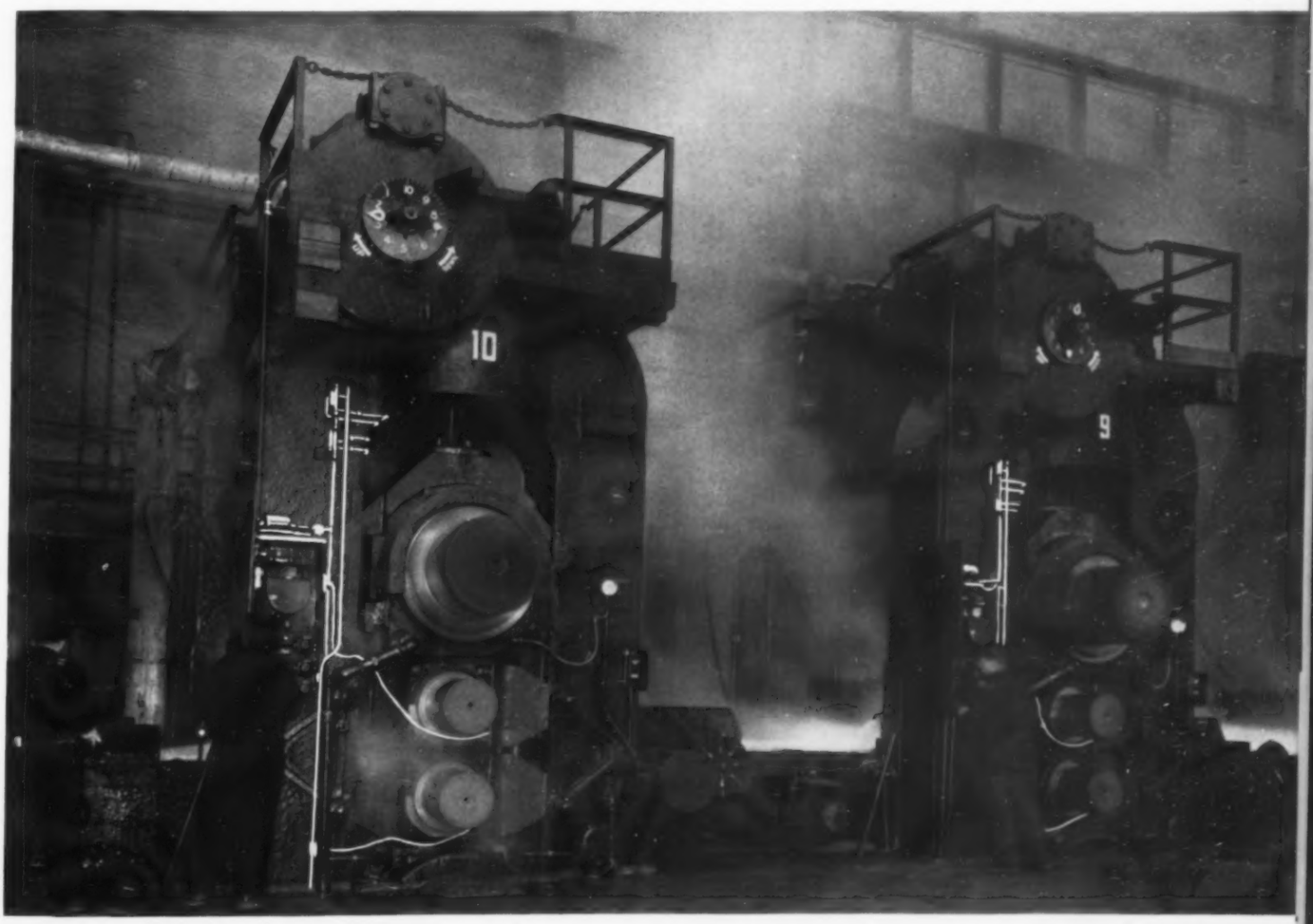
A prominent engineer recently made the statement that if the present trends were continued, he would not be surprised to see a mill built in the near future to meet the requirements of an existing lubricating system, without any regard to the production requirements of the mill itself. Ridiculous as is the picture this statement calls to mind, I do not believe it could be any more out of line with true engineering than the mills built in the past with no thought to proper lubrication, or the proper protection of bearings by means of adequate scale guards and the like. This same engineer, however, made the statement that on all future developments by his company, a thorough study of the lubrication and bearing requirements would be made, and that the proper steps would be taken to insure their incorporation in the initial design. This is a real step forward.

Lubricating practices have been undergoing very rapid changes in the past three years, and the present practices are undergoing such rapid changes that a paper describing them a month ago might easily be out of date today. The new mills which have been built in the last few years are, of course, radically different in their lubricating requirements from the older style mills. As a result of these changing requirements, new and improved lubricating mediums have been developed along with improved methods of application. Extreme pressure greases and oils have been hastily developed to meet the load requirements on bearings and gears in the newer mills. Most of these products are far from perfected at this time, but it is confidently assumed that the many experiments now being conducted will eventually lead to a solution of the confronting problems.

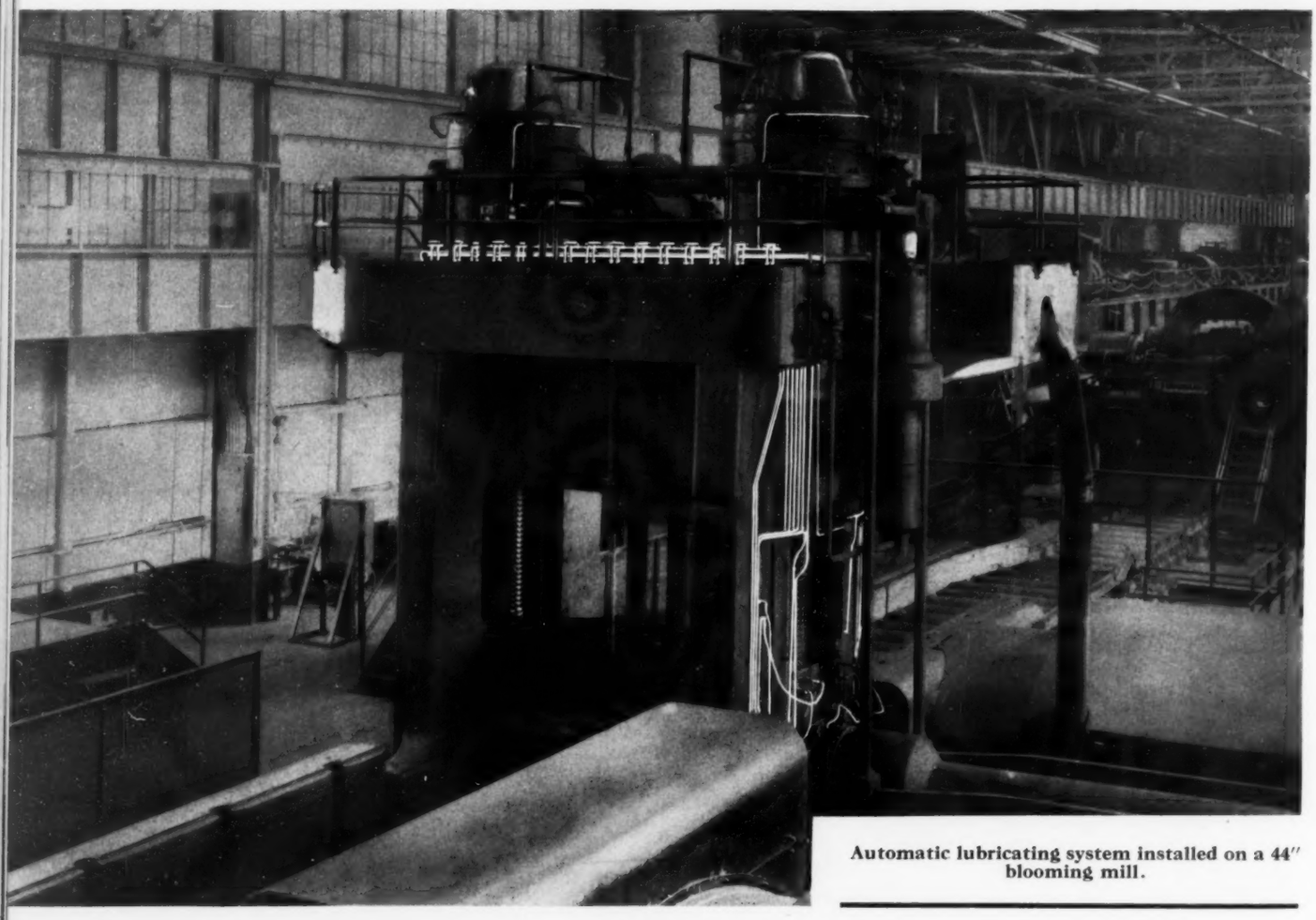
The crying need in this direction is for high-film strength oils and greases that will maintain their extreme pressure properties for a definite length of time, will be neutral in reaction, will not bleed or separate, and will either be of such high demulsibility that they can easily be separated from water, or will be altered to work in conjunction with water without the necessity of separation. Until this point is reached, however, we should go slowly on the use of E. P. lubricants unless the service is such that straight mineral oil products are definitely inadequate. There is a common tendency at the present time to use E. P. lubricants on many jobs that can be handled with ordinary lubricants.

There are several schools of thought regarding the way in which E. P. lubricants actually work. It is certain that they are chemically active and that their continued use must result in a certain amount of corrosion on the bearing surfaces or gear faces. Some of the E. P. lubricants deteriorate on standing without even being put into service. On the face of it, if this is true, it is hard to see how their use would be in any way harmful to the bearing, and the added compound would have the effect of merely increasing the load-carrying ability of the lubricant. On the other hand, it is pretty generally believed that the use of E. P. compounds causes the formation of a hard wear-resisting oxide on the surface of the bearing or gear. Chemically, this oxide could only be formed under conditions of extreme heat or extreme pressure, or both, and it may therefore be reasoned that the bearings or gears are being subjected to a form of heat-treatment after they are put into service.

To support this, we know of one case at least, where a pinion set when first installed could not be run satisfactorily on a straight mineral product. An E. P.



Automatic lubrication applied to roll necks of a hot strip mill. Emergency push buttons are applied to each stand.



Automatic lubricating system installed on a 44″ blooming mill.

lubricant was substituted with completely satisfactory results. After about three months' operation, the E. P. lubricant was drained out and the original product put back into the housing, and at the present writing, this set has been working satisfactorily for some time in this manner. In view of the different types and concentrations of E. P. lubricants, it is not reasonable to suppose that the degree of heat treatment or oxide formation would be the same in all cases, and to follow the same line of reasoning a little further, better bearing and gear life would be expected if the manufacturers of this equipment could determine the amount of such treatment necessary, and apply it in a scientifically-controlled manner before making shipment.

In further support of the theory that E. P. lubricants are chemically active on the metal itself, is the fact that one E. P. lubricant that we know of that is stable and does not deteriorate even after months of service, has not proven as successful in the field where E. P. lubricants are accepted as necessary, as the more instable compound.

As a general rule, manufacturers now recommend E. P. lubricants on gears and pinions where the loads encountered are in excess of 3,000 lbs. per inch of face. This is done in spite of the fact that there are many gear and pinion sets in service today operating under actual working pressures as high as 7700 lb. per inch of face that have given absolutely trouble-free service over a period of years on straight mineral products. In one case, a blooming mill pinion was changed after 13½ years of service, due to a broken wabbler on the coupling. The tonnage on this pinion was over 4,500,000 tons; the pressure in pounds per inch of face 7010, and the speed in feet per minute, 522. Examination showed that the teeth had worn ⅛″ in this period of 13½ yrs. This pinion was lubricated by a bath containing a mixture of asphalt pitch and cylinder oil having a viscosity of 200 sec. at 210 degrees F. There are undoubtedly many other comparable life records available, and it is therefore difficult to visualize what possible advantage can be gained by the use of E. P. products in instances of this kind.

Lubricating systems have proved their value in so many instances that they are now considered as standard equipment on all new mill installations. These lubricating systems fall into two general classes—namely, oil and grease, and there are several well-known competing companies on both oil and grease systems, each of which has its own particular champions or adherents. The installation of these lubricating systems has resulted in remarkable efficiencies in power, labor, grease, and maintenance costs. Existing costs in some of the modern strip mills are truly remarkable when

considered from the standpoint of the cost that would be experienced in the manual lubrication and maintenance of 10,000 to 15,000 grease bearings alone, in addition to all of the gears, pinions, and bearings using oil as a lubricant. In most of these mills two or three men per shift take care of all the lubricating systems. Lubricating costs, of course, vary in the different mills but we know of one large strip mill that has rolled over a million and a quarter tons that has used to date .08 lbs. of grease per ton and .02 gallons of oil per ton. In this particular mill, the only grease bearings that have been worn out or replaced have been the scale breaker bearings which are inadequately protected from scale, and several of the work roll bearings which have been damaged as a result of roll breakage. We believe this to be an excellent record, and one that other mills should shoot at.

It is not only in modern mills that lubricating systems have proved their merit. Practically all types and ages of mills are now being automatically lubricated, and with excellent results so far as grease lubrication is concerned. Centralized lubricating systems on old-style mills will yield an even greater return on the capital investment than installations in the more modern mills. The reason for this lies mainly in the type of bearing employed in the older mills. The proper application of improved types of lubricant on blooming and bar mills has resulted in almost unbelievable power and bearing savings. Mills of this type have been successfully lubricating automatically for the last 8 or 10 years. Power savings of from 10 to 35 per cent are general, and in the case of bar, merchant and other intermediate mills, bearing life has been increased from 4 to 10 times. So far as blooming mills are concerned, it is only comparatively recently that really good bearing life has been achieved. This improved bearing life has resulted from the adoption of enclosed or semi-enclosed bearings which offer adequate protection against the admission of scale. With a good home made scale guard, average figures indicate that 75,000 to 125,000 tons is about all that can be expected in the way of bearing life.

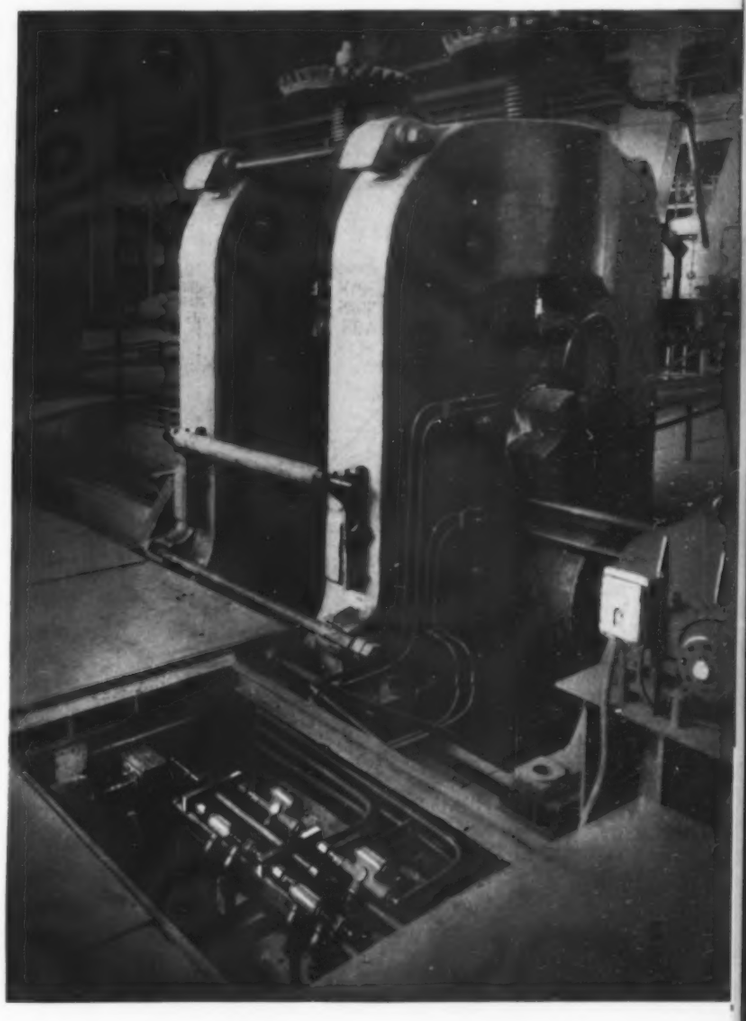
With an enclosed bearing which offers adequate scale protection, upwards of 400,000 tons can be expected. Several different types of enclosed bearings are now in use, and all of them are apparently giving excellent results. One of the best is a two-part bearing sealed on the outside with a felt or rawhide packing and relieved slightly between segments at the fillet end, so that all of the cooling water is forced out against the fillet, thereby preventing the admission of even the smallest particles of scale which might normally work their way in along the fillet. Modifications of this same type of bearing have been applied to scale breakers and can be applied to bar and structural mills with comparable improved results.

With the improvement in scale guards and bearings has come a necessity for an improvement in grease. The enclosed or semi-enclosed bearings run consistently hotter than the conventional open style bearings, and it is therefore desirable to use higher temperature greases in order to prevent excessive grease costs. In fact it is doubtful if the improved type of bearing is warranted if the grease costs encountered in keeping it properly lubricated are going to be increased very much over those enjoyed under the old method. Due to the many sizes rolled on blooming mills, both starting and finishing, it is difficult to set up a standard of grease consumption, but a good average would be from 250 to 350 lbs. of grease for a full week's operation. Many mills are using considerably more than this, but it is absolutely within the province of all blooming mill operators to achieve good bearing life on the above-noted quantities of grease.

Gears and pinions in blooming mills are most generally lubricated by bath systems employing asphalt pitch and mineral oil, or a compound grease made from heavy oil and soap, quite often containing 4 or 5 per cent graphite. Pinion and pinion-bearing life in most cases is entirely satisfactory.

Continuous intermediate mills of the bar, billet, structural and skelp type have not been given the widespread attention from a lubricating standpoint that they deserve or that has been accorded to blooming mills. Many of these mills, as well as rod and wire mills, are running on bearings of synthetic materials using water as a lubricant. Synthetic bearings where

View showing valve and tripping mechanism of automatic lubrication system as applied to hot sheet mills.



water conditions are satisfactory have been almost universally successful in mills rolling flat products where the speeds are in excess of 250 ft. per minute. In some of these installations, small amounts of grease are fed periodically to the bearings in conjunction with water, while in others, grease or oil is only applied at shut-down time, in order to facilitate the subsequent start-up. Combination bearings employing a synthetic radial surface and metallic thrust collar are being used on several small shape mills. This application, as well as the use of synthetic bearings on slow-speed mills is questionable, in the light of results that can be obtained through the application of centralized grease lubricating systems. Power savings of from 20 to 35 per cent generally result from the automatic lubrication of mills of this type, and from this standpoint alone, it is almost inconceivable that operators should continue to run on hand-packed grease bearings. As a general rule, all of the mills in this group, particularly the older ones, are in pretty bad shape, so far as the lubrication of the drives and pinions is concerned. To the best of our knowledge, the best sustained results over a period of years of operation on mills of this type are on mills where each pinion has been lubricated in an individual bath of either grease or a pitch oil mixture at a viscosity suitable for the loads and speeds encountered. Many mills of this type were originally equipped with circulating oil systems designed to supply oil from a common tank to the bearings and teeth of a number of pinions. A compromise oil had to be used in such cases as it was evident that a heavy oil suitable for the slow stands would be too heavy for the fast finishing stands. The result has been excessive wear in both the low and high speed stands. In one instance in a structural mill, the original oil system serving 9 stands was discarded after 8 years of operation in the mill. The housings were sealed up and bath lubrication of the proper viscosity oil provided for each stand. A centralized grease system was installed on the pinion bearings and felt seals were provided to prevent contamination of the bath lubricant by the grease. This system is now in its fifth year of operation, and cost sheet figures on lubrication and maintenance show a saving of $9,532.00 for the first four years of operation under the new system. This is a return of 332 per cent on the total cost of $2,850.00 which was the amount spent in making the complete change-over.

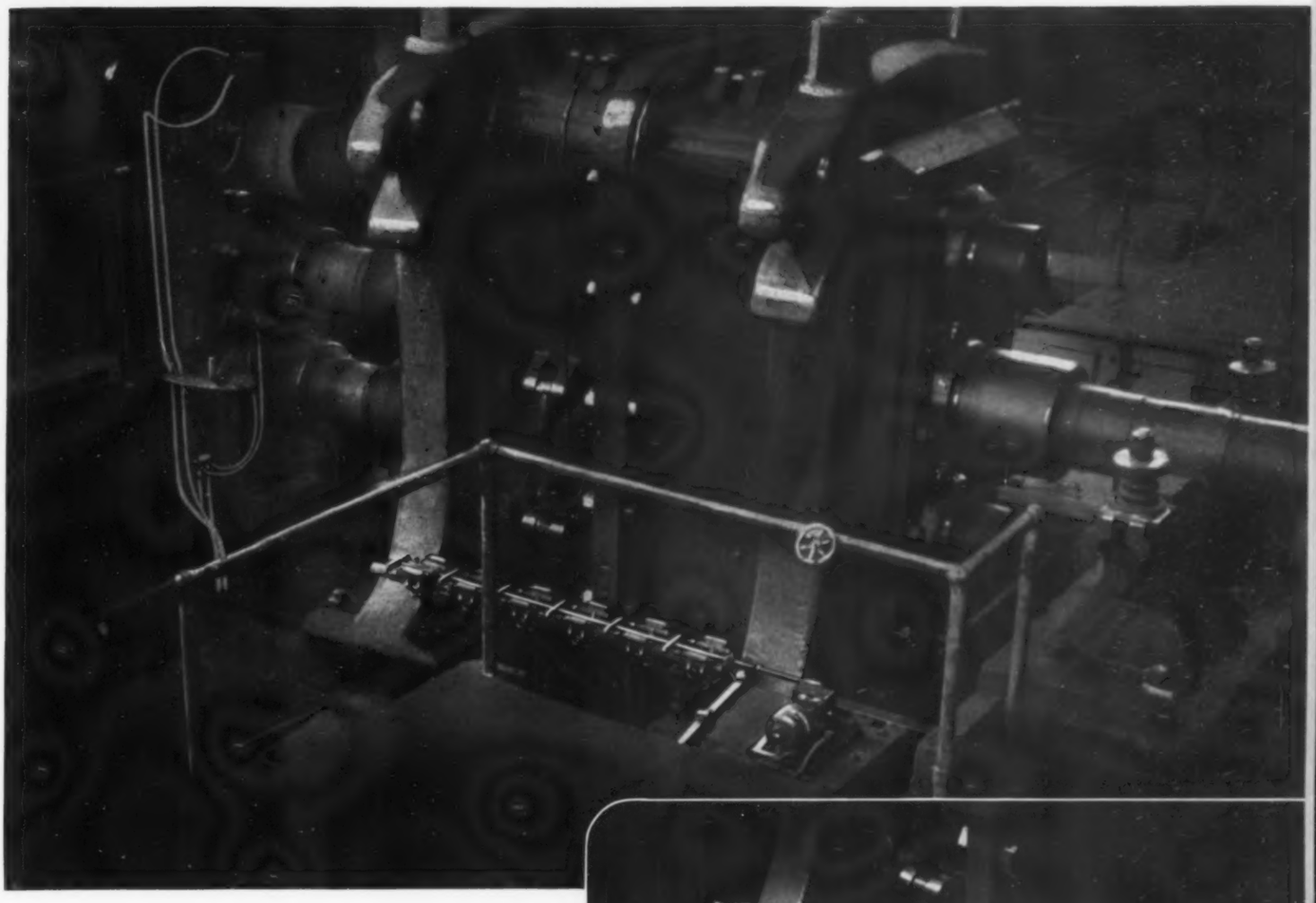
The old style two high hot sheet mill has been the last to give way to advanced methods of lubrication. It is true that this type of mill is not so important a factor in the sheet rolling industry as it was a few years ago before the strip sheet mills came into prominence, but it is also true that the several hundred remaining in use throughout the industry are important to their operators and their proper lubrication represents an ever-present problem. In order to keep pace with other sheet rolling developments, these mills have been speeded up from a tonnage output standpoint by means of pack furnaces and automatic catcher and feeder tables, to the point where they are now producing from three to six times as many tons per hour as they were ten years ago.

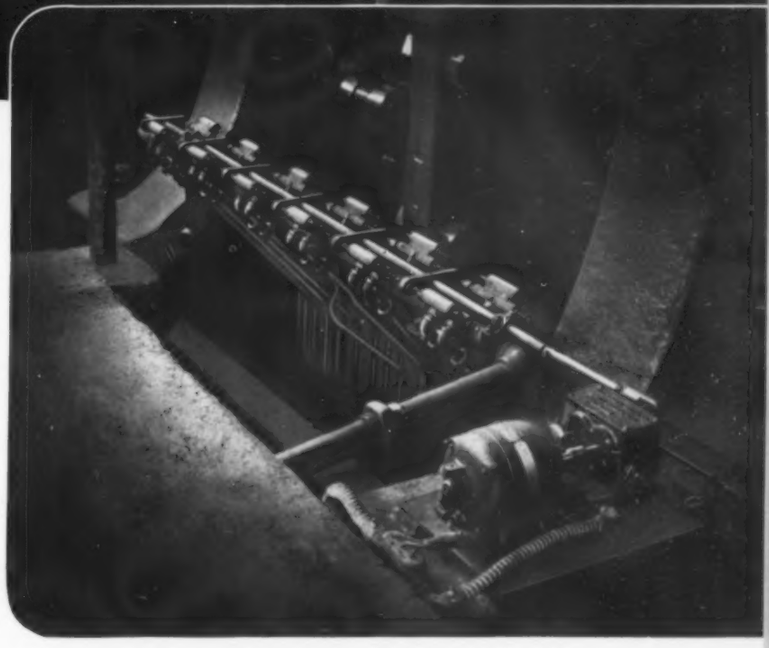
The introduction of the three-high mill as a breakdown unit has helped greatly in increasing sheet mill tonnages and at the same time has made the mills harder to control due to the fact that the shape of the breakdown from the three-high mill does not always conform to the shape of the two-high finishing mill. It is only natural that in view of the increased work given the two-high finishing mill, the lubricating requirements are proportionately more severe.

The first really successful hot sheet mill installation has been in continuous operation for over a year and a half. This installation is at the International Nickel Company's plant in Huntingdon, W. Va., where monel and inconel sheets are rolled. This metal runs as high as 80 per cent nickel content, and is rolled at a furnace temperature of from 1900°F to 2100°F. The grease used in lubricating mills of this type is extremely heavy. In order to perform its job properly, the lubricating system must be mechanically perfect, and completely flexible so as to provide independent adjustment at each mill, and be capable of delivering frequent shots of grease to each roll neck. The benefits of proper lubrication in a sheet mill are farther-reaching than might generally be expected because in this type of work, lubrication has a definite bearing on the quality of the product rolled. These benefits may be summed up briefly as follows:

Sheet rejections due to grease splash have been at least 90 per cent eliminated; power saving of from 18 to 20 per cent; increased brass life of from 200 to 400 per cent; grease saving approximately 50 per cent. Reduced neck friction has resulted in an appreciable reduction in neck temperatures. This reduced neck friction results in a better pulling mill, and enables the roller to control the shape of his mill and product in a much better fashion, and should eventually result in an improved yield. Reduced neck temperatures reduce the tapering tendency of the necks and also reduce their tendency to fire crack. Grease-handling has always been one of the worst nuisances in a sheet mill. The grease house is now completely abandoned and the pits which were formerly cleaned twice a week, are now cleaned three or four times a year. Since this first installation another sheet mill rolling stainless steel has been equipped and has been operating successfully for over a year. In this mill, due entirely to reduced neck friction, two reheatings on some of the heavier orders, and one reheating on all other orders have been eliminated. Installations are now in use on pack furnace mills where comparable results are being obtained.

Crane lubrication represents a real problem for the steel plant lubricating engineers. In the finishing departments, the dripping of lubricant from cranes to finished material is very costly, and in other departments where heat and excessive dirt are encountered, maintenance is almost universally excessive due to premature bearing failures resulting from insufficient lubrication. Some plant superintendents are opposed to centralized lubricating systems for cranes on the grounds that hand-lubrication is desirable because it is accompanied by inspection which is regarded as essential. Particularly in hot and dirty shops, lubrication is required more frequently than inspection, and available figures show that centralized systems have resulted in maintenance savings of approximately 40 per cent, labor saving for lubrication and inspection of 50 per cent, and grease savings of 50 per cent. There





(Top) Automatic lubricating system as applied to roll necks on a 24″ merchant mill.

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(Bottom) Close-up of tripping mechanism. Each valve is independent, so that one valve becoming inoperative does not affect operation of the others.

is also a corresponding reduction of the safety hazard attendant to inspection and hand-lubrication.

In British mills, lubrication practice is essentially the same as the American practice so far as hand-lubrication methods are concerned, but they have been considerably more backward in adopting improved mechanical lubrication than has been the case in this country. There are probably several reasons for this hesitancy. In the first place their tonnage demands have not been so severe, labor is cheap and plentiful, and efficient means of application, as we know them, have only very recently become available. Many of the older blooming or cogging mills, as they are called, produce only 3,000 to 4,000 tons per week. Most of these mills were originally equipped with three-part bronze bearings which may be compared to a top or bottom brass, and two side brasses. The usual method was to chunk hard grease into the opening between brasses. Many of these mills are still running without any scale guards on the bottom rolls at all. It obviously would be almost impossible to do very much in the way of mechanical lubrication with such a bearing design, but in one instance, at least, improved conditions have resulted from the installation of a home-made lubricating system which provides a continual drip of gear shield onto the necks.

In a number of mills, babbitt bearings and bronze grids similar in design to those in general use in our

mills have been installed. Some of these are hand-packed with hard grease, while a few are being lubricated with automatic grease systems. These lubricating systems, with one exception, are small rotary type grease guns which hold only about 25 lbs. of grease. They have not proved very successful due to the fact that they are not of sufficiently rugged construction to withstand steel mill usage nor to handle greases sufficiently heavy to adequately protect the bearings. In several instances, these units have been discarded as failures because the soft grease used in them resulted in an excessive grease cost which, combined with the high cost of mechanical maintenance, more than offset any improvement in bearing life and power consumption. Power savings have not been comparable to savings resulting from installations in this country due mainly to the fact that the mechanical short-comings of the equipment have prevented continuous operation on well-lubricated bearings which is essential if power savings are to be realized. In only one case was a bearing life of over 30,000 tons found, and in this instance, in a new mill, the original set of bearings lasted for about 125,000 tons, but subsequent bearings fell far short of this mark, and at the present time, synthetic bearings are being used in this mill. These synthetic bearings are still in good shape after 75,000 tons, and at the present time are considered satisfactory.

A new blooming mill now being erected in England is being equipped with flood oil bearings. The effectiveness of this installation will be very interesting to watch as it may point the way for similar developments in this country. Bar and merchant mills are most generally equipped with solid brasses. In a few instances, babbitt bearings are used, and in one or two cases, synthetic bearings. The operation as well as the methods of lubrication on these mills is comparable to similar old-style mills in this country. A very good grade of bag grease is used quite generally as a lubricant for these mills, with apparently very good results. At least one lubricating system has been installed on a cross-country bar mill and discarded, because of its mechanical failures. Several installations of American type lubricating systems are now under construction on mills of this type.

While synthetic bearings have not as yet been used to a great extent in England, their limited use has proved very successful in most cases. In at least one case, a soluble oil water mixture is being used as a lubricant for synthetic bearings with very good results, after disappointing results had accompanied the use of plain water. Old-style hot sheet and tin mills which far outnumber any other type of mill in England are still lubricated in the old way.

Several attempts have been made in the last few years to apply mechanical lubricating systems and improved lubricating greases to these mills, but so far, none have been successful. This is probably due to the fact that the lubricating systems which have been tried were not capable of handling greases heavy enough to meet the various requirements. Several installations similar to those now in use on hot sheet mills in this country are under consideration at the present time.

There are now two modern strip mills under construction in England, both of which are being equipped with American-type centralized lubricating systems for both oil and grease. There are also several other modern mill installations employing roller bearings that have been put into service within the last several years. Most of these are using oil systems on roller bearings, as well as on the gears and pinions.

Mechanical crane lubrication has advanced farther proportionately than mechanical lubrication in any other department in the British steel plants. In spite of the fact that these installations have been very costly when compared to the cost of mechanical crane-lubricating systems in America, they are favorably looked upon from an investment standpoint, and in most cases are working very satisfactorily, due probably to the fact that the equipment is not mishandled to the extent that it would be in the mills proper, and also to the fact that it can efficiently handle the soft lubricants that are desirable for crane lubrication.

While the steel plants in England have been hampered from the standpoint of availability of practical methods of application, they have at their command exceedingly good lubricants. British lubricant manufacturers who, by their own admission, ranked a poor third to the United States and Germany up until a few years ago, now have plenty of evidence to support their claim of superiority in the industrial lubrication field. American grease manufacturers with British subsidiaries are in several instances using British formulae in their compounding of greases. This is particularly true of E. P. lubricants. British E. P. lubricants are most generally made from naphthenic acids derived from Roumanian crudes. This product is particularly potent in an E. P. compound, and in addition, is apparently more stable than naphthenic acids derived from any other source of crude. Another example of the ingenuity of British lubricant manufacturers, while not particularly relevant to this discussion, is interesting. High demulsibility oils have always been regarded as essential to turbine lubrication. In spite of this there is a turbine now running in England that has been in continuous operation for over a year using water and soluble oil as a lubricant in a ratio of 25 to 1. This is a transparent soluble oil, transparent even in solution with water, of very high film strength, and periodic inspections of the turbine have indicated that the soluble oil and water lubricant will function just as efficiently as a high demulsibility oil.

In the opening paragraph of this paper, proper lubrication was described as the combination of the proper grade of lubricant plus its proper application. Proper application involves a lot more than the mere purchase and installation of a lubricating system, and unless the lubricating system is properly designed to meet the existing conditions, successful results cannot be achieved. This is true of both oil and grease systems. Existing records of past experience show us that different viscosities of lubricants should be used in gear and pinion sets to take care of the varying conditions of speed and load. If these records mean anything, it does not seem reasonable that one lubricating system can be installed to take care of the gear or pinion sets throughout a continuous mill, where the speeds and loads vary over a wide range. The common practice in modern continuous mills is to install one oiling system for all gears and another for all pinions. Mills using this system have had trouble, particularly on the broad

side mill where excessive loads are encountered, and it has already been recognized that this particular stand should be lubricated with about a 3,000 second viscosity lubricant, although the oils in general use in the other stands are only 1750 second viscosity on reduction gears, and 2400 second viscosity on the pinions. Since it has already been proved that these general system oils are too light for the broad side mill, it is also probable that they may prove too heavy for the No. 9 and No. 10 stands, where excessive speeds are encountered. It would therefore seem to be logical that the best method of lubricating gears and pinions would be to provide at least two or perhaps three reduction gear oil systems, and a similar number of pinion oil systems. In view of the reduced pipe sizes that would be involved in these smaller installations, it is doubtful if such a method of installation, even in view of the additional equipment involved, would be more extensive than the completely centralized systems now in general use. Such a procedure would, of course, increase the number of units to be maintained, and to a certain extent, at least, eliminate the definite advantage of complete centralization which is now enjoyed, but the net result would probably show a material increase in equipment life.

Parallel to the above practice for oil systems, we find some mills lubricating plain bearing roughing stands and scale breakers from the same centralized grease system as roller bearings, in order to eliminate duplicate piping and purchase of additional equipment. Other mills are using one system for roller bearings and a separate system with a different type of grease for plain bearings. This latter method has proved much more economical from a standpoint of grease consumption. Another common fault in grease lubricating systems which has proved extremely costly from a grease-consumption standpoint has been to lubricate the mill by sections rather than with regard to the bearing requirements. In other words, the pumps have been located at various points throughout the mill and all bearings within a radius of 75 to 100 ft. have been lubricated from that station. In some instances, we find table rollers, pull backs, side guard adjustments, chutes and loopers, back-up rolls, and work rolls, all being lubricated at the same time interval. While it is true that quantity valve adjustments help to remedy this obviously impractical method of installation, they fall far short of being the answer to it. Over-lubrication or perhaps over-selling on the part of the lubricating system manufacturers has become a very serious matter in larger installations. The result of this is excessive capital expenditure for the equipment and installation, and excessive maintenance costs, and it can only lead eventually to the discrediting of centralized lubrication by the steel mill operators.

The steel industry needs proper lubrication. Proper lubrication can only be achieved if sound engineering principles are applied to the design and installation of grease and oil-lubricating systems. To achieve this desired end, it is essential that the engineers and operators of the industry recognize the problem and cooperate with equipment manufacturers to the extent that each installation, regardless of manufacture, be installed in such a way as to provide adequate protection for all bearings, complete flexibility to take care of changing requirements and emergency conditions, and still provide economy in lubricant consumption, maintaining meanwhile, the greatest possible degree of centralization.

DISCUSSION

PRESENTED BY

L. F. COFFIN, Superintendent, Mechanical Department, Bethlehem Steel Company, Sparrows Point, Maryland.

F. J. THOMAS, Lubrication Engineer, Republic Steel Corporation, Cleveland, Ohio.

C. R. HAND, Lubrication Engineer, Bethlehem Steel Company, Sparrows Point, Maryland.

J. W. KIGHT, Penola, Inc., Pittsburgh, Pennsylvania.

R. M. GORDON, Gordon Lubricators Division, Blaw-Knox Company, Blawnox, Pennsylvania.

R. P. DUNMIRE, Vice-President, Buckeye Laboratories, Alliance, Ohio.

H. E. MEYER, General Master Mechanic, Great Lakes Steel Corporation, Ecorse, Michigan.

E. S. GLAUCH, Mechanical Engineer, Joseph Dixon Crucible Co., Jersey City, New Jersey.

L. F. COFFIN: I quite agree with Mr. Gordon regarding the advisability of installing more lubricating systems in some cases in order to be able to use more nearly the correct lubricant in varying speed and pressure drives. Particularly in cases of high speed mills using sleeve type bearings on rolls, it is usually advisable to have two bearing oil systems, one using higher viscosity oil for the lower speed oil pressure stands and the other using lower viscosity oils for the low pressure high speed bearings. In such a mill it may also be necessary to have two additional systems, one for lower speed high tooth pressure gear drives and the other for higher speed lower tooth pressure gear drives. The necessity for separating the bearing oil systems from the gear drives is brought about by the ever present possibility of water contamination in the bearing systems, which contamination it is desirable to keep out of the gear drives.

F. J. THOMAS: The very interesting and instructive paper presented by Mr. Gordon covers, as he stated, a remarkably wide range of closely related topics. I am sure we must all agree with his concluding statement concerning the need for the application of sound engineering principles to the problem of lubricating the machinery of the steel industry, both by the equipment builders and our own engineering departments.

In discussing some of the points Mr. Gordon has

touched upon, permit me to say that in designing systems to lubricate our equipment we should make every possible effort to keep them as simple and direct as possible. Equipment builders and engineering departments, by focussing their attention on making machinery easy to lubricate and properly protected against leakage or contamination of lubricant, can do more than anyone else to liberate the lubrication engineer from the necessity of using complicated and expensive lubricating systems. It should not be necessary to be a second "Rube Goldberg" to be able to figure out ways to lubricate machinery which the equipment builder sends into the plant. And to the everlasting credit of our progressive equipment manufacturers, let it be said that that necessity is passing rapidly.

I would like to repeat, however, my belief that a stand should be taken against creating too complicated lubrication methods and systems in our plants. Let whatever systems are available for oiling and greasing be used where necessary, as sound engineering principles and sober judgment dictate.

Having had the opportunity to study the operation of practically every type of oiling and greasing system in the plants where they are in use in this country it is my opinion that any one of them can be used with real success when properly adapted and applied to any individual problem. After this has been done, the system will operate just as well as it is maintained. I might add that I have seen home made combinations of several greasing systems working very efficiently and economically. These systems are tools, which if properly applied to the right job, can be of real service in helping us to lubricate our equipment efficiently.

Concerning the use of EP lubricants, these are, to my knowledge, performing a much more important service and are being much more widely used in steel mills than is generally realized. They supply added protection to gears and roller bearings which might, upon occasion, be subjected to emergency overloads. They should not be regarded as cure-alls, however, with the idea of correcting or alleviating fundamental defects in gear design, capacity-rating or workmanship.

The idea expressed, that gears and pinions in a large hot strip mill would be better served by a larger number of circulating systems than is now the general practice, does not appeal to me. I do not believe that varying viscosities of oil are needed for the various pinion stands in a hot strip mill, nor do I consider that it has been proved that a 2400 viscosity extreme pressure oil is too light for a broadside or any other pinion stand in a modern hot strip mill. The straight mineral oil viscosities quoted by the author, have I believe, come into some use merely through guesswork and have no actual scientific background as have the viscosities figured for some of the present oil-film bearing applications.

With roller bearing equipped reduction gears and pinions, I believe the oil systems in the hot strip mill might even be further simplified by using one system only for both reduction gears and mill pinions, and using a suitable extreme pressure oil. There will be, of course, an honest difference of opinion concerning this.

In discussing the use of separate greasing systems for grease lubricated plain bearings on roughing stands and scale breakers, these have been successfully designed for the use of roller bearings, oil film bearings or even fabric bearings, eliminating the use of separate greasing systems.

I wish to express my personal appreciation of the paper Mr. Gordon has presented and the interesting and valuable information contained in it.

C. R. HAND: Mr. Gordon's paper has been very interesting. Too much stress cannot be laid on the importance of proper lubrication. Millions of dollars are lost each year, through neglect of some important phase. The principal phase is most frequently overlooked, that is, the original design and specifications for the metals comprising the equipment.

Too often buyers accept improperly designed equipment and then worry along with it until they themselves can redesign or discard it. It frequently happens that manufacturers will agree to make changes, but at additional prices, or set delivery dates back so far that the buyer cannot wait, or insist that Tom, Dick or Harry has the same equipment and has no trouble. Occasionally drawings and specifications are received two or three days after the equipment has been shipped. All these factors work against good lubrication.

There seems to be considerable misunderstanding in the EP lubrication field. Some have gone so far as to recommend that machines be designed for EP lubricants only, whereas the engineers and chemists who have developed these compounds, are frequently forced to it, because some designers have failed to make their gears and bearings strong enough to do the work required. It is realized by most engineers, that EP lubricants have their use and do a good job, but there certainly is no reason why we should eliminate all the excellent oils and greases now used. Each piece of equipment should be carefully investigated and the proper lubricants used. The assumption that EP lubricants will cure all troubles and prevent all surfaces from wearing, is not proven in practice.

The use of composition bearings is and should be confined to old mills or new mills where other types cannot be economically used. Much work and patience has been expended in the development of composition bearings. There are, however, many problems still unsolved, one of them being variation in quality.

Mention is made of present practice of installing one oil system or one grease system for an entire mill. This practice should be vigorously opposed. Although the high speed mills may be lubricated with a light oil, certainly the low speed should not be. Some of the continuous sheet bar mills erected 10 or 15 years ago were equipped with three systems. However, at that time, heavy oils were used in all. Operators have reduced the viscosity in the finishing high speed gear drives to about one-half of the original viscosity.

The use of individual control of greasing cycle on each stand has proven to have many points in its favor. It is obvious that mills travelling at 300-600 rpm. need grease at more frequent intervals than the

roughing mills do at 30 rpm. With the centralized system, the interval remains the same for all.

Mr. Gordon's paper has emphasized that good lubrication begins in the original designs. Operating engineers have the problems after the equipment is installed. They have accumulated much experience and data on gears, bearings and seals. If we are to improve our future equipment, the operators must submit their information to the manufacturers. And —the manufacturers must agree to change their designs to incorporate changes, that have been proven in actual practice, It is only by whole hearted cooperation of all concerned, that we can hope to get trouble free equipment.

J. W. KIGHT: I would like to say something on the subject of E. P. lubricants. The growing use of E. P. lubricants has been thoroughly discussed on a number of occasions. In these discussions it is frequently stated that the equipment manufacturers are at fault because they design machinery that will not stand the loads when lubricated by a straight mineral oil. It is also stated that lubricant salesmen stress E. P. lubricants because they involve a greater margin of profit. However, it is my belief that the major cause for the growing use of E. P. lubricants in steel mills is found in the use to which equipment is put after it is installed. For example, the mill builder designs a mill to roll a certain range of product. Six months after the mill is in operation the production people decide to roll lighter gauges and wider widths than that for which the mill was designed. Failure of the equipment under those conditions is not the fault of the mill builder. Likewise the maintenance people cannot be blamed for discontinuing the use of a straight mineral oil and going to something that will carry these heavier loads. There are very few strip mill operators who have not faced the problem, after starting up a mill designed to roll only as far down as .075, of having the sales department come in after they have been going for three months and wanting them to roll barrel stock at .044. I feel that is the reason why most mills have gone to E. P. lubricants.

On the question of the corrosiveness of certain E. P. lubricants, I would like to ask Mr. Gordon if he has found that all E. P. lubricants are corrosive.

R. M. GORDON: No.

J. W. KIGHT: And whether they all separate?

R. M. GORDON: I know of one or two that do not separate. I mentioned in my paper that these stable products are not as successful in the field generally ascribed to E. P. lubricants as the more unstable ones.

J. W. KIGHT: I would like to touch on another point which was mentioned in Mr. Gordon's comprehensive paper, and that is the use of graphite in greases. As we all know, graphite has come in for a lot of discussion at various times, and a number of people have said that it is a "cure all", which it is not. Graphite has certain definite places where it is applicable to the benefit of all concerned. I would like to point out that the manufacturers of grease handling equipment would do well to design their equipment to handle graphite grease, particularly where the equipment feeds the lubricant to rollnecks.

R. P. DUNMIRE: In discussing lubrication problems generally, at the meetings of the Association of Iron and Steel Engineers, we have given considerable attention to proper bearing designs for given applications, which was well warranted.

Also considerable discussion has come to pass regarding a means for securing more effective lubrication under high bearing pressures, especially with compounds known as extreme pressure lubricants. These compounds have proven quite effective in many instances. However, they are quite often misapplied and used without a thorough study being made as to the particular use and applications under which they are to be operated.

I wish to place more stress on the proper maintenance of non-compounded petroleum lubricants. Such oils function within very narrow limits and the use of extreme pressure additives is not necessarily a cure-all for bearing trouble encountered in practice.

It must be considered that immediately a lubricant is put into service, deterioration of its function with respect to oiliness and film strength, begins to become apparent. It is, therefore, of great importance that the maintenance methods used in the handling of oils be such as to maintain their effectiveness by keeping them free of contaminants to the greatest degree possible without injury to the oil.

The effects of most contaminants are fairly well known. However, we recently made a very interesting study of the effect of various contaminants on the film strength and breakdown pressure of oil films. These data also included the use of certain EP additives, and it was shown definitely ,that by proper servicing of the oil so as to remove the contaminants to the greatest possible extent, that not only higher breakdown pressures of the film resulted, but also considerable savings in the amount of input power and consequent lowering of bearing pressure were effected.

These studies indicated that the use of EP additives were not necessary in many cases where the oil is used under conditions where it is well serviced. It was also indicated quite clearly that the benefit obtained from various types of EP additives varied considerably. Therefore, great care should be taken in applying additives to see that they are adaptable to operating conditions and will not cause excessive deterioration of the oil, or the loss of valuable physical characteristics of the oil itself.

C. R. HAND: I would like to say a word in regard to graphite as a lubricant. Unfortunately, the various grades of graphite on the market are not all graphite. I have analyzed some samples and found as much as twenty-five per cent ash. Certainly those graphites with that amount of ash would not be as good a lubricant as some of the electric furnace graphites we now have, and I think it is due to that particular reason that graphite has somewhat fallen from grace.

H. E. MEYER: Mr. Gordon has presented some interesting facts concerning the extent to which lubricating systems are being used both here and abroad,

and has covered the subject in such a way that we can readily see that progress is being made in pressure lubrication.

Long before a practical greasing system was introduced to the steel mill, the millwright and maintenance man were trying to accomplish the same results with make shift apparatus, using oversize grease cups, some screwed down by hand and others worked by means of weights. The modern greasing system has been a great improvement over the old time methods and has simplified maintenance work to a great extent, but there is still room for much improvement. It is just in the last few years that we have seen bearings developed for blooming mill rolls, that are totally inclosed, lubricated by a pressure system, supplied with water, and equipped with a substantial and effective scale guard, all in one unit. Forward strides are also being made in lubricants that can be successfully applied, creating a saving in labor and grease costs.

The machine builders are also recognizing the value of the pressure grease system, but a closer study of pressure system application will no doubt result in provisions being made by the builders, to provide the necessary cavities, grooves, etc., to hold and distribute the lubricant, when it is brought to the bearing, pin or trunion by the pressure system.

On some of the late installations the lubricating engineer has done his work well, but his system is not effective because provisions are not made to make the best use of the grease when it reaches the outlet. Our experience with pressure systems has brought us face to face with their good and bad features. We believe the tendency is to make one central pump or unit reach too far, that is the lines are too long for some of the greases being used.

It is sometimes necessary to substitute a light bodied grease for a heavier kind in order to avoid trouble with clogged lines, resulting in loss of effective lubrication. It would also be a decided improvement, we believe, if the distributing valves would be mounted on a substantial base, and shipped to the job as a unit, designed to feed a specified number of outlets. This would make adjustments easier to maintain.

We are grateful to those who have spent time and energy to develop the present lubricating systems and believe they have been brought to a point where constructive criticism will result in a much improved article. There are still "bugs" to be worked out of the present apparatus. The systems are not wholly automatic, but are regarded as such by the average attendant, and any neglect on his part can easily result in damage to equipment.

E. S. GLAUCH: Mr. Kight in his discussion mentioned the fact that in many cases the graphite grease is desirable, particularly on some of the older types of mills and graphite grease does an excellent job of lubricating and he felt that the manufacturers of lubricating systems should take some steps to design and manufacture a system that will properly handle a graphite lubricant.

Mr. Hand discussing this stated that he had tested in some cases graphite greases where the analysis indicated that the graphite contained as high as 25 per cent of ash.

The writer wishes to state that there is no need or no reason why grease manufacturers should use a graphite containing as much ash as mentioned by Mr. Hand in that high grade, natural, lubricating graphites can be obtained for grease manufacture that will run 90 per cent graphitic carbon and there are other grades that will run from 97 to 98 per cent graphitic carbon and the small amount of impurities in a grade of this type is not at all detrimental from a lubrication standpoint. If one considers a graphite containing only 2 per cent of ash, and the graphite content of the grease even as high as 20 per cent, the percentage of ash in the finished product will be less than ½ of 1 per cent.

There have been many thousands of pounds of graphite grease for steel mill work produced in the last few years containing graphite running 97 to 98 per cent graphitic carbon and from reports obtained, this grease has given excellent results on heavy duty mills; in fact, better results than could be obtained with other greases.

Some years ago the writer presented before the Chicago section of this organization a paper on rolling mill lubrication and at that time presented figures showing the power savings that were possible when using graphite greases in competition with plain or non-graphite greases on rolling mills. In some cases these power savings ran as high as 25 per cent. The writer would, therefore, agree with Mr. Kight that some effort be made to design the system so that it will handle graphite grease for undoubtedly there are many mills on which a graphite grease will give better lubrication than a grease which does not contain graphite.

Continuity of POWER SUPPLY *for* STEEL MILLS... AS INFLUENCED BY RELAYING AND SYSTEM DESIGN...

By E. H. BANCKER and R. H. KAUFMANN

GENERAL ELECTRIC CO.

SCHENECTADY, N. Y.

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▲ IN the discussion of a subject such as relaying which is only an incident to the making of steel, it is worth while, even at the risk of stating things that you all know, to step back and get a perspective of the entire situation and the part played in it by the relaying.

The business of a steel mill is of course the making of steel and the sale of it at a profit. To accomplish this you frequently install entirely new equipment just for the purpose of increasing the efficiency and reducing the cost of production. The ability of this equipment to earn a return on its investment and effect the economies anticipated depends upon its uninterrupted use when wanted. Hence, even though the generation and distribution of power is only incidental to the production of steel, the efficient use of a large investment in steel producing machinery requires that some attention be given to continuity of the power supply.

The chief enemies of continuous supply of power are mechanical failure of the equipment conveying the power or an insulation breakdown. The purpose of all forms of protection is the prevention of these failures or reduction of the harmful after-effects of one in case it does happen.

Much can be done to improve the quality of service by proper design or the use of protective equipment to prevent the happening of failures in the first place. For the prevention of electrical failures, this means the inclusion of adequate insulation or a reduction in the voltages allowed to appear across it. Mechanical failures can be avoided to a large extent by locating equipment so that it is free from mechanical hazards or by shielding it.

Adequate maintenance also goes a long way toward anticipating failures by finding and weeding out potential causes of trouble before they develop into an actuality.

Despite all efforts to avoid them, experience shows that there will still be cases of insulation failure, but the deleterious effect of these can be minimized through the provision of reserve capacity and alternate power routes with adequate relaying. By these methods it becomes possible to provide an exceedingly high degree of availability of power at important load centers.

FUNCTION AND PRINCIPLES OF RELAYING

The purpose of protective relaying is the selection and disconnection of the minimum faulted area required to relieve the system of the distress caused by a short circuit. This selection should be accomplished in the least possible time in order to minimize the disturbance to the remainder of the system and the damage at the point of fault. Stated in another way, this means that *only* the faulty machine, transformer, bus, or line should be cut off, and it should be done quickly enough to avoid loss of synchronism, dropping out of undervoltage protection, or the stalling of motors supplied by the remainder of the system.

There are, of course, innumerable other functions performed by relays, but these fall under the general classification of control rather than protection, and are not included in this paper.

The selection of the defective equipment is accomplished by a comparison of quantities that have different values or ratios under fault and normal conditions, often in combination with time.

The three electrical quantities used in all relaying for protecting against electrical faults are current, voltage and the angle between currents or between a current and a voltage. These quantities may be those existing at one point or at different points in the circuit depending upon the type of relaying used. Almost any combination of them may be employed under different cir-

cumstances. Several of the ones most frequently used will be discussed starting with the simplest one.

An overcurrent relay compares the current expected during a fault condition with the maximum existing under other operating conditions. The actual comparison is, of course, made as you all know by giving the relay a minimum operating setting that is in excess of the maximum load but below the minimum expected fault current.

The theory of time overcurrent relays is to select the breaker nearest the fault through the introduction of graded time settings so arranged that the relays nearest the fault operate first and each succeeding relay nearer the source of power somewhat slower. Thus, a fault on a remote feeder will start a number of relays in operation, but the one on that particular feeder will trip its circuit breaker before any other relay closes its contacts. The same is true of each section nearer the source in that its relay will be faster than those on the other sections between the faulty one and the source.

The time action may be definite or vary inversely with the current magnitude. As a matter of fact, all relays are inverse over some part of their operating region and use may be made of this fact to secure selective time intervals without straight addition of definite time steps to each successive relay nearer the generating source.

Due to the difficult maintenance conditions that exist in many locations in a steel plant and having in mind the vital importance of maintaining electrical service at important locations, such as the open-hearth department, the main pump house, by-product substations, etc., the use of "cascaded" time overcurrent relaying schemes has been almost entirely eliminated in the larger more modern installations that have been made since 1928. Any important modernization of the switching in an existing plant should also tend to eliminate cascading in favor of the thoroughly-proven and dependable pilot-wire or line-differential relaying schemes on the important tie lines.

Since the ratio of voltage to current is the mathematical expression for impedance, relays comparing these two quantities are usually termed impedance or distance relays. This type of relay compares the magnitude of the current and voltage and if the current exceeds a certain ratio to the voltage, it indicates a short circuit within the adjacent line section. Faults outside of that line section will cause a higher voltage or lower current to exist at the relay location and hence will not cause operation.

Impedance relays usually consist of several impedance responsive elements, a directional element and a timer. The impedance element set for the lowest impedance trips immediately when it operates providing the direction is right. This setting is ordinarily about 90 per cent of the impedance of the line to which it is applied. The second impedance element is set for the length of the line protected and about 50 per cent of the shortest line beyond the bus at the far end. This element trips through a timer with enough delay so that if the fault is beyond the end some other relay and breaker can clear it, but if it is within the remaining 10 per cent of the line not covered by the instantaneous element, it will clear when the time expires. The third impedance element usually covers all of any adjacent line beyond the remote bus and trips through a still longer time contact on the timer. It is also used to set the timer in operation. This element should never have occasion to trip any fault except when some other relay or breaker combination has failed to do so.

Impedance, or distance, relays are more accurate in rapidly locating a fault than the overcurrent relays previously mentioned, because their operation is dependent upon a characteristic of the line protected rather than upon the system setup.

Another form of distance relay is the reactance type in which the fault is located by comparing the reactive component of the voltage (IX drop) with the current instead of comparing the whole voltage with the current. Such relays have the advantage over impedance relays of being practically unaffected by the arc resistance at the point of fault.

Reactance relays usually contain one or two reactance elements, a timer and a starting unit. The reactance elements and timer perform the same functions outlined under the description of impedance relays. The starting unit is a voltage-restrained directional relay which combines in one unit the directional action and a sort of impedance characteristic. This element corresponds to the third impedance element and the directional element of the impedance relay.

Where only one reactance element is used, it is set normally for about 90 per cent of the adjacent section line reactance and trips immediately for faults within this zone, if the directional element permits. If it does not trip immediately, indicating that the fault is further away, the timer resets it for a distance equivalent to a line and a half after waiting long enough to allow any more remote relay to clear if the fault is outside of the protected line. Thus, a single element performs the function of two elements.

It is frequently necessary to prevent tripping for a flow of current in one direction and permit it when the current flows in the opposite direction. To accomplish this, relays are used which compare the angle between the current and voltage at the relay location. The relay will rotate one way for currents lying in two adjacent quadrants with respect to the voltage and the other way for currents in the other two quadrants. The dividing line may be placed at any desired angle with respect to voltage, usually between 30 and 60 degrees leading so that all fault currents in the lagging quadrant will produce a good torque. Relays of this type are essentially wattmeters with the angle of maximum torque occurring at some lagging current rather than at unity power factor.

With rare exceptions, directional relays are supplementary to other relays such as overcurrent, impedance, reactance, etc., and are installed for the purpose of keeping them from tripping under conditions when they should not.

Directional relays may be single-phase or polyphase and if single-phase, may be connected to receive either the individual conductor currents or the residual current of the three current transformers if the system neutral is grounded.

Directional relays may prevent tripping by other relays by opening the trip circuit or they may actually prevent the operation of the other relays. The latter method is frequently used in connection with over-

current relays where the operating torque is nil until the directional relay contacts close. This method has the advantage of avoiding a race at the end of a fault in the non-tripping direction which has resulted in closing the overcurrent relay contact and which must then open before the directional relay closes after the fault has been cleared by the proper breaker.

As mentioned in connection with reactance relays, the addition of voltage restraint to a directional relay gives it somewhat of an impedance characteristic. The zero torque axis remains at the same angle (that is, somewhere in the leading quadrant) but the voltage restraint moves the axis parallel to itself so that a definite amount of current is required to cause operation even at the angle of maximum torque. A device of this nature is able, therefore, to serve as both a directional and a fault-detecting element.

True differential protection is an application of Kirchoff's law that the sum of all the currents entering a point is zero. The point, of course, may be expanded to be a generator winding, a bus, a transformer, or a transmission line and the law still holds. In true differential relaying, all the currents entering and leaving an area by all known paths are added and the sum energizes a relay. This sum is normally zero, but becomes the total fault current when current departs by some unknown route. This principle, which forms the basis of the best protective relay schemes, is applied in its pure form to generators, large motors, buses, and short lines by paralleling the secondaries of current transformers in all branches of each phase and applying the resultant current to an overcurrent relay.

Differential relaying is also applied to transformers in a similar manner by comparing the currents in the several windings of each phase. This is not quite true differential because the currents are not equal to each other, but they do bear a constant ratio to each other unless there is a fault within the transformer. By proper choice of current-transformer ratio, secondary connections, and the use of secondary auto-transformers or tapped relay coils, the net effect on the relay is made zero except when an internal fault exists.

For long lines where the cost of circulating the secondary currents from one end to the other would be prohibitive, a scheme of differential protection is sometimes employed in which the secondary current is converted to a voltage at each end by passing it through an impedance and then the two voltages are opposed. The result is the same as if the currents had been circulated since the relay is connected to operate in accordance with any difference in voltage, which means any difference in currents at the ends.

There are many modifications of differential relaying which are employed where the cost of true and complete differential protection is not justified. Examples commonly encountered are discussed in more detail below.

When the obstacles comparing the currents at the opposite ends of the line are prohibitive, recourse is often had to a comparison of the currents at the same end of two parallel lines. This is an expedient that is not as good as a direct comparison of the two ends of the line because it does not give complete protection against all short circuits.

The comparison may involve magnitude only where the defective circuit is sure to have the greater current. Relays utilizing this principle are known as balanced current relays. Frequently the comparison involves angle as well as size where the unbalance is largely in direction as at a receiving station fed by two parallel circuits. For a fault in one of the lines, the fault current is the same in both, but in one it flows toward the receiving station bus and in the other away from the bus, and this fact can be utilized to select the faulty line. For a fault on the bus or on a feeder off of the bus, the currents in the two lines are equal and no relay action follows.

In some pilot, and all carrier-pilot schemes of relaying, only the angle of the currents at the two ends of a circuit are compared. This is done indirectly by comparing each current with its local voltage by means of directional relays and then comparing the resultant position of the relay contacts at the ends of the line by means of the pilot channel. While the comparison is not direct, the voltages at different points in a system are near enough in phase with each other to serve as a standard of reference except when the system is out of step and this is taken care of by other means.

DIFFERENTIAL RELAYS

The relays used for differential protection are many and varied in speed, sensitivity, and other characteristics. If current transformers gave a perfect reproduction of primary current at all times, any true differential would require only a simple instantaneous overcurrent relay to distinguish invariably between faults within the differentially protected zone and those external to it. Unfortunately this is not the case because the iron in the current transformers has a saturation curve that is not linear and the exciting current for their cores is abstracted from the primary current. Even in a generator differential scheme where there are only two supposedly identical current transformers carrying equal primary currents, experience shows that there may be a difference current in the relay during external faults.

Down the years there have been several ways of preventing unwanted relay operation. The simplest and cheapest is to raise the minimum operating current setting of the relay until it is above the differential current existing during an external fault. This, however, greatly reduces the degree of protection afforded by the relay. Another equally simple and inexpensive solution is the substitution of an inverse time relay which does not detract from the sensitivity but does prolong an internal fault. For the past several years it has been common practice to employ the external fault current itself to restrain the differential relay without affecting its sensitivity and speed. Modern generator differential relays have one winding which receives the difference current and tends to operate the relay and a second winding energized by the circulating current that restrains the relay. It is customary to have the minimum operating value about 0.1 ampere secondary with 10 per cent restraint. This means that at full load on a machine, a fault current of about 0.5 ampere secondary is required to cause operation of the relay.

In transformer differential protection there are three other factors present to increase the probability of

difference current when there is no internal fault. First, the current transformers are not alike as they are different in primary rating and usually in construction because of the difference in voltage rating. Secondly the power transformer usually has taps which are occasionally changed so that the ratio of the currents in the high and low tension windings is not always constant. Lastly, there is frequently a large transient exciting current when the transformer is suddenly energized, which has no counterpart in the other winding. These conditions make it necessary that a transformer differential relay be less sensitive than a generator relay, that it have a higher percentage through-current restraint, and that it have either a time delay or some desensitizing mechanism so that it will refrain from operating throughout the magnetizing inrush period. Transformer differential relays ordinarily have a pick-up of about 2 amperes and a 25 per cent restraint characteristic.

Bus differential relaying presents a slightly different problem than either a generator or transformer because the path of an external fault current is not known in advance and because the different current transformers are operating at different degrees of saturation. In a few cases through-current restraint may be used but in the usual case there is no place to insert the restraining coil and be certain that it will restrain for all external short circuits. Obviously, the use of a restraining coil, per circuit connected to the bus, becomes impracticable when there are more than about three circuits. The usual practice in the past has, therefore, involved a differentially connected time-over-current relay, sometimes supplemented with a high set instantaneous attachment.

The most recent advance in this type of protection is the harmonic restrained overcurrent relay. All secondary difference currents arising from ratio errors in current transformers contain a large harmonic component, since the difference current is an exciting current and iron core excitation currents always contain harmonics in the saturation region. The harmonic restrained relay separates the fundamental from all the harmonic currents and employs the former to operate and the latter to restrain operation of the relay. The result is a very fast and sensitive relay for internal faults with a sense of discrimination that enables it to distinguish between fault current and exciting current differences even when the latter is larger.

GROUND RELAYING

Normally a relay is energized from a current transformer in each of the phases. Relays so connected are influenced by load currents as well as fault currents. Usually a relay is also inserted in the common return lead of the current transformer secondaries so that it is responsive only to ground current. Since the ordinary load currents do not flow through this residual relay, there is no lower limit to its setting as there is in the case of the phase relays and sensitive ground fault protection is obtained.

In general, all of the types of relaying discussed may be applied for faults between conductors and also from conductor to ground, although it is rare to find ground distance relaying because of the complexity. Residual

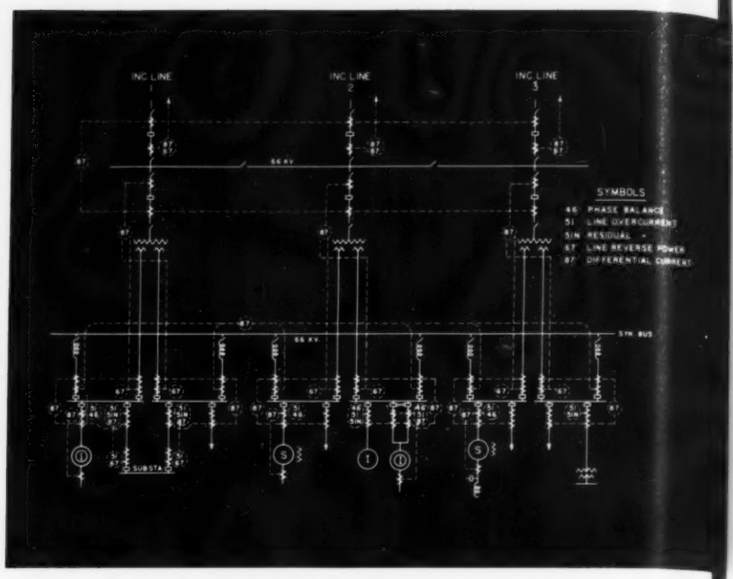


FIGURE 1—Typical relay applications to a steel mill distribution system.

relaying for a grounded neutral system has several advantages among which are the possibility of setting the relays for a low current and a smaller area over which faults attempt to operate the relays.

SUMMARY

Other types of relaying than pilot-wire introduce undesirable time delays in the clearing of certain types of faults, and in addition require more maintenance than the relatively simple types of relays used with pilot-wire. The following order of preference, therefore, seems natural, bearing in mind both the performance and the maintenance requirements:—

First Choice	Second Choice	Third Choice
Pilot-wire relaying.	Impedance or reactance-block directional relays.	Ordinary directional overcurrent schemes.

Protective relaying is one of the most important forms of insurance against delays and shutdowns in a steel plant. Under the severe operating conditions that prevail in a heavy industrial plant, short circuits and faults are a recognized contingency. The problem of protecting the proper functioning of the steel-making facilities from these unpredictable disturbances in the electrical transmission system and its connected machines is best answered by proper and complete relaying in conjunction with modern adequate switchgear.

Figures 1 and 2 illustrate actual applications of relaying principles herein discussed. Although represented to be merely typical of modern practice, they

are based on real installations and portray more than hypothetical systems using theoretical relay combinations.

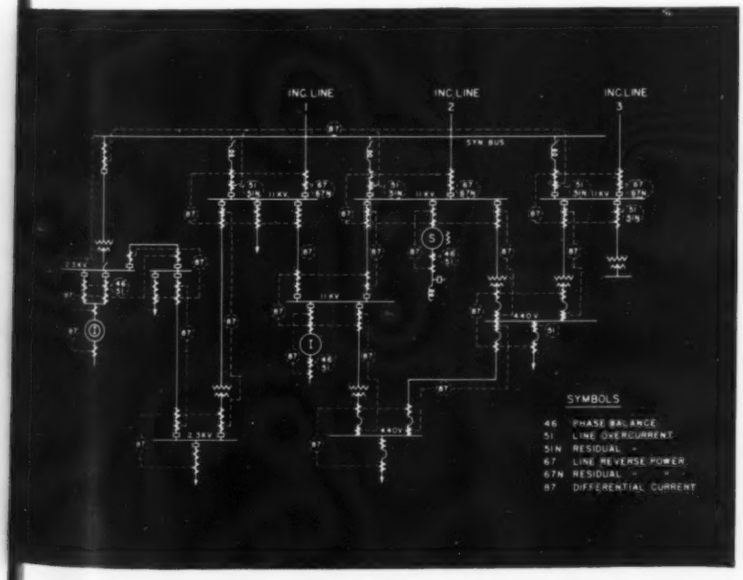
SYSTEM DESIGN

Intelligent inspection and careful maintenance will, of course, minimize but will not abolish the ocurrence of electrical faults on the distribution system. Adequate effective relaying systems are applied to automatically isolate a particular element of the electrical system in case it becomes involved in a fault. During the time the fault remains on the electrical system, the general level of line-to-line voltages is depressed and may be readily diminished to such an extent as to jeopardize service continuity of load equipment considerably removed from the point of fault. Considerations of service continuity cannot be divorced from electric system design. The system design and layout directly affect the stability margins obtained both under normal and fault conditions. The influence on type and permissible settings of relays also indirectly affects the problem under discussion.

For adequate power supply to important secondary load centers, alternative sources should be available. If the reliability of a single primary power bus can be reasonably assured, secondary source reliability can be obtained through the use of multiple feeder circuits with individual switching equipment at the terminals combined with adequate relaying. It is important that the system design be as simple and direct as possible consistent with the attainment of the desired degree of reliability as indiscriminate interconnection of the secondary load centers with various primary sources can become extremely detrimental. In general, such excess interconnection tends toward higher short circuit current magnitudes, increases the difficulty of securing adequate selective relaying, tends to increase the area suffering a severe voltage disturbance as a result of one particular electrical fault, and may very readily result in poor utilization of feeder distribution copper due to unbalances in the division of load current throughout the network.

Reliability of main and secondary power buses is, of course, essential to uninterrupted service. Many different types of bus construction have been used in the past in an attempt to obtain a higher degree of bus reliability. A common system used in conjunction with cell type construction employed a double bus structure with suitable transfer switching to allow either bus to be used to carry the entire load. Not only is such a system quite costly but requires greater space and presents greater operating hazards resulting from switching errors. The present trend is toward metal-enclosed structures using a single bus whose reliability is practically assured by the most careful consideration of all design factors, and the incorporation of a higher insulation level than exists on external circuits. Steel enclosed compartments isolate current and potential transformers. Steel panels separate instruments, relays and the bulk of the control wiring from the main power conductors.

FIGURE 2—Another typical application of relays to a steel plant distribution system.



SHORT CIRCUIT CURRENT MAGNITUDE

During the growth of an industrial plant, the electrical distribution system is being correspondingly extended and increased in its aggregate kva. capacity. Unless curbed by the application of a planned system of short circuit control, the short circuit duty throughout the distribution system would be expected to increase along with the expansion of the electrical plant and may greatly exceed the optimum values consistent with best overall economy. Higher levels of short circuit duty demand the application of more expensive switching equipment and necessitates very careful consideration of all current carrying elements to insure ample mechanical strength and thermal capacity to withstand the current flow incident to short circuit. High values of short circuit current also involve other detrimental factors which both directly and indirectly influence general continuity of power.

A summary of the more important of the undesirable influences would include:

1. The necessity for using switching equipments of comparable high short circuit interrupting capacity and short time current carrying ability with the attendant increase in first cost.
2. The problems incident to assuring adequate mechanical strength in bus structure, oil circuit breakers, disconnecting switches, current transformers, etc., are greatly increased. The difficulty increases very rapidly as the short circuit current magnitude increases above 60,000 amperes and becomes almost intolerable at 100,000 amperes. Even below these limits, considerable difficulty will be encountered if short circuit current magnitudes exceed, say, 100 times the normal rating on a single outgoing feeder circuit.
3. In a given system, the higher the fault current, the greater will be the resulting voltage drop

throughout the system. By intentionally restricting the possible flow of short circuit current by means of the application of suitable current limiting impedances, properly located, the average voltage in the distribution system during the existence of the fault will be increased.

4. The presence of high values of possible short circuit current greatly increase the problem of obtaining correct selective time relaying since the time margin between relay time-setting steps diminishes as the possible short circuit current increases.

   The greatest care is required in the application of current transformers to insure ample size to withstand mechanical stresses. The inadvertent application of a small ampere rated current transformer in a feeder circuit, subject to high short circuit current magnitudes, may result in the destruction of the current transformer before the associated relay can operate in the event of a feeder fault. In such a case, equipment is destroyed; the entire bus section to which this feeder is connected will be shut down; and the prolongation of low system voltage pending operation of back-up protection may result in shut down of apparatus in surrounding portions of the system. To assure adequate short circuit protection in such an instance would require the application of a current transformer whose rating is not at all commensurate with the normal current rating of the circuit.

5. The difficulty of applying bus differential protection which will definitely not operate on external faults is increased due to saturation of current transformer. In the presence of large magnitudes of short circuit current, a more elaborate and expensive form of bus differential relaying may be necessary to assure correct operation.

CONTROL OF SHORT CIRCUIT CURRENT

The limitation of short circuit current to reasonable levels will pay real dividends both in the form of reduced first cost of the electrical distribution plant and as a result of improved service continuity. Usually the justification of a particular system of short circuit control is judged on the basis of savings in initial switching costs alone. One should not lose sight of the other benefits simultaneously attained.

The benefits are the direct opposites of previously mentioned undesirable influences and include:

1. Permissible use of less costly unit switching equipments made possible by reduced rupturing capacity and short time current rating.
2. The problem of assuring adequate mechanical strength and thermal capacity in all circuit elements which must carry the short-circuit current is greatly reduced and savings in equipment cost may be effected.
3. The assurance that short circuit current levels now existing in the present plant will not be noticeably affected by possible future expansion and extension.
4. Improved performance of time overcurrent relaying.
5. Average system voltage during the existence of a particular secondary fault is increased.

To reduce short circuit current demands increased impedance between the source and the point of fault. This effect may and should be accomplished insofar as possible by means of the inherent reactance in the essential circuit elements such as line transformers.

The use of series reactors in the power circuits should be limited to the smaller capacity feeder circuits, insofar as possible. Their use for short circuit control becomes less effective as the normal ratings increase.

For example, the insertion of a 10 per cent reactive voltage drop in a 50,000 kva. circuit would limit the line short circuit duty to 500,000 kva. A three-phase reactor for this purpose would be rated 5,000 kva., would consume 5,000 reactive kva. and approximately 75 kw. at full load.

The insertion of a 10 per cent reactive voltage drop in each of ten independent circuits rated 5,000 kva. would limit the short-circuit duty on each circuit to 50,000 kva. The individual-circuit three-phase reactors would be rated 500 kva. and at full load would consume 500 reactive kva. and approximately 11.5 kw.

The total power being transmitted in both cases is 50,000 kva. In both cases the aggregate R kva. consumption is 5,000 kva. The power losses are comparable being 75 kw. for the single 50,000 kva. circuit and about 115 kw. for the ten 5,000 kva. circuits. The short circuit duty (from the supply system) on the 50,000 kva. circuit is 500,000 kva. while on each of the 5,000 kva. circuits is 50,000 kva.

If the circuits also contain synchronous apparatus in proporionate amounts, the additional short circuit current so contributed to the single 50,000 kva. circuit would be expected to be about ten times as great as that to each of the 5,000 kva. circuits.

Fortunately, electric power distribution systems generally lend themselves to considerable control of short circuit current magnitudes without increasing the reactance between the source and the load under normal operating conditions.

Sectionalization

In moderate to large capacity distribution systems, the aggregate power source usually consists of a number of individual transformers or generators and power is distributed from the main central stations by way of numerous individual feeder circuits. Such a system lends itself to short circuit control by sectionalizing. By combining a given individual source or group of such sources aggregating possibly 7500 kva. at 2300 volts or possibly 25,000 to 50,000 kva. at 6600 volts with a group of feeder circuits of approximately the same aggregate kva., a unit system results which is capable of independent operation. It is undesirable to completely isolate the various units in the system as that sacrifices the ability to benefit from the diversity of loads on the various unit sections and complicates the problem of providing standby capacity for each such section. A suitable system of sectionalizing reactors (of which the synchronizing bus arrangement is a typical example) provides the ability to supply full capacity standby power to one unit system from the others with moderate losses and voltage regulation.

The ability to exchange marginal power between sections to take full advantage of the diversity factor in the total plant load is obtained with almost insignificant losses (power and reactive kva. losses in the sectionalizing reactors vary as the square of the transfer current).

Under normal operating conditions with substantially balanced loading, there is practically no interchange between units by way of the synchronizing system and the overall system operates with the same efficiency, voltage regulation, and total maximum power capacity as if all unit systems were solidly interconnected.

In the event of a severe electrical fault on one section, however, only the directly associated power source can deliver its full value of short circuit current as limited by the inherent reactance of that source and all others must feed through the sectionalizing reactances which definitely limit the magnitude of short circuit current so contributed.

Feeder Reactors

The application of current limiting reactors inserted in the secondary feeder circuits may be justified in many instances. The magnitude of short circuit current can be reasonably restricted to much lower values than could be obtained on the main distribution bus and yet retain adequate voltage regulation and maximum power capacity. At the same time, the presence of the feeder reactor acts as a cushioning element in the event of a short circuit on that feeder permitting a fairly reasonable voltage to be maintained on the main distributing bus in the presence of a solid 3-phase fault on the feeder circuit. It is often possible to maintain a bus voltage of at least 90 per cent during the existence of a solid 3-phase fault on the feeder which has reduced the potential of the latter to zero.

The application of feeder reactors shows increasing benefits as the number of branch circuits fed from a given feeder increases because all of the branch circuit switching units are subject to equal savings in first cost. An increased number of branch circuit per feeder also increases the possibility of a secondary circuit failure and consequently the value of maintaining adequate bus voltage in the presence of a feeder circuit fault becomes more valuable.

The application of a reactor to a feeder circuit supplying power to a single load unit can practically never be justified.

NEUTRAL GROUNDING

On industrial electric power distribution systems, the ideal objective of securing immediate selective fault isolation with no disturbance to operating equipment not involved in the fault can be more closely approached by the use of a grounded neutral.

The electrical neutral of a symmetrical power distribution system, inherently assumes earth potential in the absence of system faults. It is obvious that under normal operating conditions, an electrical inter-connection between the system neutral and earth will have no influence on the electrical system. Connecting the electrical neutral point to earth, either solidly or through a current limiting impedance, gives the system the ability to circulate a ground fault current in the event of an electrical failure between any one phase and ground within the confines of the common metallically connected electrical system. The maximum magnitude of ground fault current can be readily restricted to any desired value, by the choice of neutral impedance, without altering the performance of the power distribution system under normal operating conditions.

In the event of an electrical failure involving ground, on a grounded neutral system, the ground fault current component travels out over the line conductors, having a common direction and phase in all three lines, and returns by way of the earth to the system neutral ground connection. By a very simple connection of current transformer secondaries, it is possible to establish a circuit in which only the ground current component flows. The magnitude of current in this auxiliary circuit is proportional to the sum of the ground fault current components in three line conductors and normal power currents are entirely excluded, so that it is unnecessary for the relay to differentiate between normal power and fault current. It is at once apparent that such a system possesses a tremendous advantage from a relaying standpoint since any flow of current in this auxiliary circuit is a definite indication of the existence of an electrical fault. A more sensitive relay with more rapid time characteristics is thus permitted.

There are other outstanding advantages of a grounded neutral system which aid in the attainment of a higher order of electrical power continuity which will be subsequently enumerated.

CHARACTERISTICS OF AN ELECTRICAL DISTRIBUTING SYSTEM DURING THE PRESENCE OF A SINGLE LINE-TO-GROUND FAULT

Ungrounded Neutral Operation

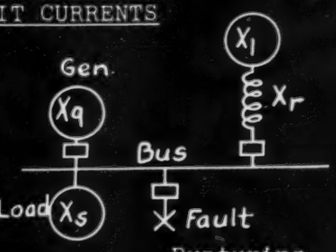
1. Selective relaying impossible, due to the absence of fault current.
2. Possible sustained operation of the distribution system with displaced neutral, such that the line-to-ground potential of each of the two unfaulted lines becomes line-to-line voltage.
3. Under certain conditions, arcing ground phenomena occur which may give rise to excessive line-to-ground potentials on the two unfaulted lines.
4. Line-to-line voltages are unaffected.

Solidly Grounded Neutral

1. Selective ground fault current relaying possible.
2. High magnitudes of ground fault current which result in:
   a. Considerable disturbance in the line-to-line voltage delivered to load equipment.
   b. Required rupturing ability of oil circuit breakers may be established by line-to-ground fault current magnitude.
   c. Severe mechanical stresses may be set up in the unit which is serving as the neutral grounding element, particularly if a rotating machine is used.

EXPECTED INITIAL SHORT CIRCUIT CURRENTS

Based on Gen. KVA Rating
X_q = Gen. sub-transient Reactance = 12%
X_1 = Equiv. connected system Reactance = 3%
X_r = Tie Reactor Reactance = 10%
X_s = Syn. load Equiv. Reactance = 25%



Gen. Rating	Initial Unsym. RMS Amps. 2400 V.	4150 V.	6900 V.	13800 V.	Rupturing KVA
6250 KVA	52000	30200	18200	9100	110000
7500 "	62500	36200	21800	10900	133000
12500 "	104000	60200	36200	18100	221000
18750 "	156000	90500	54500	27200	332000
25000 "	209000	121000	72500	36400	442000
37500 "	313000	181000	108000	54500	663000

FIGURE 3—Chart of expected initial short circuit currents for various generator ratings.

d. The occurrence of a line-to-ground fault within a load machine may cause the frame potential of the latter to be considerably displaced from earth potential due to the presence of appreciable resistance in the grounding circuit.
e. Neutral voltage shift on the distribution system, although theoretically zero, assumes considerable magnitude on moderate to large capacity systems, due to the inherent resistance in the system neutral earthing connection.

Resistance Grounded Neutral

1. Selective ground fault current relaying possible.
2. Absence of arcing ground phenomena can be assured.
3. Predetermined maximum fault current of moderate value which result in:
   a. A neutral potential shift of not more than 58 per cent of line-to-line voltage which exist only while fault current is flowing.
   b. A very minor disturbance in the voltage delivered to load apparatus.
   c. Controlled stresses in the machine serving as the grounding unit.
   d. A tremendous reduction in the possible magnitude of frame-to-earth potential in a load machine involved in fault.

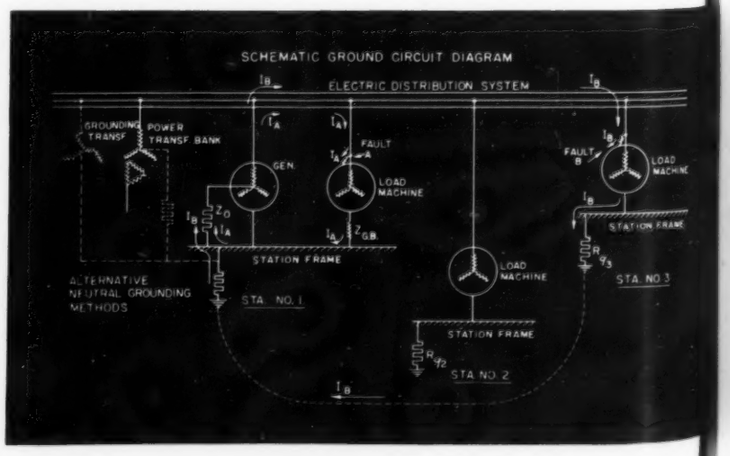
The apparent advantage of an isolated neutral operation is largely lost in the case of an industrial distribution system such as involved in steel mills because:

1. Single ground faults cannot be automatically isolated and are difficult to locate.
2. During the existence of such a fault, two line conductors throughout the entire metallically connected system operate with full line-to-line potential from line to ground which is 73 per cent above the normal value and when sustained favors the occurrence of another line-to-ground fault possibly in another machine.
3. In certain cases, a fault of arcing character will produce expensive potentials of several times normal line-to-line value between the two unfaulted conductors and ground.

The only advantage which a solidly grounded neutral system possesses over a resistance grounded neutral system is represented in the belief that line-to-ground potentials are being held to normal values at all times. In systems of moderate to large size this will ordinarily not be realized as will be illustrated in the following example.

Figure 4 illustrates a portion of a distribution system containing three stations. Number one contains a generator which will be used for earthing the system neutral. Number two and three may be considered as substations. Each station contains an interconnected

FIGURE 4—Diagram of a portion of distribution system containing a generating station and two substations.



metallic structure which in turn is earthed in the station ground connection.

With solid neutral ground (Zf = O), a single line-to-ground fault in the same station, such as at A, will often result in a ground fault current of greater magnitude than line-to-line fault current. This heavy current (often in excess of 50,000 amps.) may produce excessive mechanical stresses in the generator used for neutral grounding. The circulation of this heavy current through the ground conductor from the load machine in fault to the station frame may result in considerable voltage drop creating a hazard to station personnel.

Under similar conditions, consider a line-to-ground fault at number three station such as B. In this instance the fault current must flow through R_{g1} and R_{g3} in series. Assuming ½ ohm ground resistance at each station, it is apparent that the current permitted on a 6600 volt system will be 3810 amps.

Such a current would result in a voltage drop across R_{g1} of about 1900 volts. The entire station frame would be displaced from earth potential by about 1900 volts. Throughout the rest of the system, this appears as a neutral displacement voltage on the electrical system. At station number 3 a neutral displacement voltage of 3800 volts would appear.

A so-called solidly grounded neutral system thus affords no assurance that neutral displacement voltages will be eliminated.

With the loss of this apparent advantage of the solidly grounded neutral system, it is advisable to intentionally reduce and stabilize the magnitude of ground fault current by the introduction of a current limiting impedance Z_o. The magnitude of ground fault current should be established at a value which will provide ample residual current for relaying purposes on the largest circuit so protected. A total secondary residual current of about 2 amperes is normally sufficient.

The resulting system retains ground fault selectivity and avoids the disadvantages encountered in solidly grounded neutral operation.

METHODS AVAILABLE FOR GROUNDING THE SYSTEM NEUTRAL

The power system neutral can be grounded at the Y point of a Y-connected rotating machine or at the corresponding point on a transformer bank providing the latter also contains a delta connected winding.

The unit used for neutral grounding purposes shall be of sufficient size to permit normal ground fault current flow in addition to continuous normal power current flow for an internal of two minutes without reaching excessive temperatures.

The current limiting impedance may consist of a reactor or resistor although the use of a resistor provides greater assurance of freedom from unusual transient voltage surges coincident with ground fault occurrence. This element normally carries no current and is usually rated on a two-minute interval of full magnitude ground current flow.

In the absence of suitable Y-connected machines or transformers, a grounding transformer may be supplied having three line terminals for connection to the system line conductors and a neutral lead for connection to earth. Under normal conditions only magnetizing current flows and it is again conventional to rate the grounding transformer on a 2-minute interval of full magnitude ground current flow. The grounding transformer is usually designed with sufficient inherent reactance to directly limit the ground fault current to the desired value making it unnecessary to use supplementary current limiting impedance.

In the event that a line-to-ground fault should fail to be isolated by automatic opening of circuit breakers in response to relay action, it becomes necessary to otherwise cut off the flow of ground current to prevent injury to the unit serving to ground the system neutral. If the machine which has been functioning to ground the neutral is to be removed from service, this function should be transferred to another unit.

To meet these requirements and impose the least possible interference on utilization machinery, it is preferable to allocate the function of neutral grounding to a machine used for power supply. The entire responsibility for distribution system performance is then under common personnel and direction and is in no way compromised by considerations of load machines.

A summary of the desirable features possessed by a current limited grounded neutral system follow:

SYSTEM VOLTAGE DISTURBANCE DURING THE EXISTENCE OF A FAULT

A large proportion of electrical system failures originate as single line-to-ground faults. Inasmuch as the magnitude of fault current in this instance has been limited to a low value, the disturbance in line-to-line voltage delivered to load equipment is of very minor order. The presence and location of the electrical fault can be established by suitable zero sequence relay equipment, and it is very often possible to completely isolate the faulty section of the system before the fault develops into one of line-to-line or 3-phase character. Even though the fault develops into one of more serious character during the process of circuit isolation, the duration of the more severe voltage disturbance is reduced.

The fact that ground fault current can be readily segregated from normal power current at any desired point in an electrical distribution system permits the application of a sensitive quick-acting relay, operating in response to ground current flow only. The absence of power current component in this relay circuit eliminates the necessity for a compromise to prevent operation due to temporary overload, motor starting current, or any other power surge occasioned during normal operation.

MACHINE DIFFERENTIAL PROTECTION

The presence of a grounded neutral on a power distribution system considerably enhances the protection obtained from machine differential relays of the character which compare the current at one end of a winding with that at the other end of the same winding. A large percentage of machine winding failures will be initiated either as a line-to-ground failure, usually at

the edge of the core stacking, or as a turn-to-turn failure within a particular coil.

In general, line overcurrent relays, if present, will not be operated as a result of a turn-to-turn failure until the arcing has progressed to such an extent that several coils are involved. In the case of an ungrounded neutral system, differential relays will not be operated until the arcing has progressed to the point where more than one phase of the machine winding is involved. In the case of a grounded neutral system, however, the first contact of the arc with the core structure or frame gives rise to a differential current in that particular phase motivating the differential relay to disconnect the machine from the a-c supply and remove field excitation in the case of a synchronous machine. With an original fault either of line-to-ground or turn-to-turn nature, it is to be expected that the arc will contact the core or frame much sooner than it will burn through to another phase. The more rapid clearing of the machine, made possible by ground fault current flow, means less destruction to coils and a reduced amount of iron burning.

The simplicity, sensitivity and low cost of residual current relaying, coupled with its ability to function promptly in response to a fault involving ground, makes possible the attainment of a high order of fault protection approaching that of the differential relay. Such protection can be economically justified for much smaller machines and individual load circuits than would ordinarily warrant the use of differential relay protection.

OTHER FEATURES

The fact that the ground fault current has been limited to a definite maximum value of the order of a thousand amperes affords positive assurance that load machine frames will not be appreciably displaced from earth potential as a result of ground fault-current flow through the impedance of the ground connection to the machine frame. The possible danger to insulation of a directly connected electrical machine or shock hazard to station personnel is avoided in all cases of fault involving ground at only one point on the system.

The possibility of excessive line-to-ground potential resulting from arcing ground phenomena is definitely prevented. In general, a neutral grounding connection which provides sufficient current for positive selective relay operation will be adequate to prevent the occurrence of these abnormal transient voltage surges.

To earn the anticipated return upon the investment in steel making machinery, it is necessary that the plant be able to operate continuously when in use. This requires an adequate and properly designed power system in combination with effective relaying.

General principles of relaying and elements of system design have been briefly outlined and specific applications have been used to illustrate how these principles may be applied to improve service continuity.

While the steel industry is already among the leaders in excellent electric system practice, you will undoubtedly reach an even higher degree of perfection through the better use of new knowledge and equipment.

It is hoped that this paper will contribute in some small way toward the attainment of that better service continuity which is sure to exist in the future.

DISCUSSION

PRESENTED BY

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G. B. DODDS: This paper covers the major factors to be considered in the design of a power system to supply adequate service to industrial loads, and outlines the general types of protective equipment which are available for adequately maintaining this continuity of service.

In regard to system layout and design, it is felt that the authors' remarks on system grounding as affecting relay operation and continuity of service are very important. It may be of interest to cite the experience of the Duquesne Light Company on their underground 11 Kv cable system in this connection. This system originally started as free neutral system, but as the system grew the need for a grounding source in order to automatically clear defective feeders was recognized and a grounding bank and resistor were installed. This served satisfactorily for a period of time until the system grew larger and the cables which had been in service began to deteriorate due to electrolysis, sheath burning and other causes. When this occurred, an increasing number of so-called simultaneous cable faults were encountered, in which a cable would fail at one location and the rise in potential to ground of the other two phases would cause a failure at the same time on another cable in another location. This not only took out two cables at once, but also was frequently accompanied by incorrect operation of protective relays caused by reversal of polarity of directional elements which occurs during simultaneous line to ground faults on different phases of different cables at different locations. This incorrect polarity caused trip-outs of good feeders at locations which frequently caused extensive dropping of load.

Investigation was made of the benefits which might be obtained by reducing the amount of resistance in the system neutral, at the conclusion of which the resistance was materially lowered with a resultant

marked decrease in the number of simultaneous cable failures. The value of the impedance used at present is still sufficiently high to prevent high fault currents and also to prevent too severe voltage drops during line to ground faults. Along with the reduction in value of neutral grounding impedance, improvements were also made in the cable system such as flame proofing cables in manholes, replacement of cable in poor condition, and gradual elimination of the weak spots due to previous failures; also improved technique in making splices. It is, therefore, difficult to say how much of the improved performance is due to either cause, as each has contributed its share.

In regard to protection of overhead lines, it is important not only that the faulty line be isolated, but also it is desirable that it be isolated quickly enough so that, if possible, the damage is not permanent and the line is able to be returned to service immediately. In this respect, both the clearing time and the magnitude of fault currents are important, as well as the size of the conductor. We have found that where 4/0 bare conductor is used, if the clearing time is kept below 1 second, a burndown of the conductor is not apt to be experienced. Also, insulator damage is not apt to be sufficiently great as to prevent return of the circuit to service. In the case of smaller wire size, clearing time must be decreased. In the case of insulated wire, it is very difficult to get fast enough clearing to prevent burndown as the arc is held at one spot where the break in insulation has occurred and cannot travel over the wire as in the case of bare wire.

In some cases, the greatest amount of selectivity between faulty sections does not always give the best overall performance. For example, if three or four timing steps are required to get selection between different sectionalizing points, sometimes called "cascading", the clearing time of faults near the feeding point will be relatively high. If momentary interruptions are not too important, better overall performance might be obtained by taking momentary outages at some locations in order to decrease the clearing time of faults over a greater part of the circuit, on the basis that if the faults are cleared quickly, permanent damage will not result and the circuit may be returned to service immediately. This, obviously, is applicable only on overhead circuits where faults are apt not to be permanent.

One of the most important points in regard to continuity of operation is the elimination of instantaneous under-voltage devices on motors or their supply feeders. A short circuit fault anywhere on the supply system results in low voltage. This low voltage will be transmitted to all parts of the system. Obviously, if stantaneous under-voltage devices are installed, some of them may operate even at points remote from the fault, even though they are on feeders not involved. If sufficient time delay is provided on these under-voltage devices, there is a good chance of the motors continuing in operation, provided the low voltage does not last for too long a period.

D. C. NELSON: This paper has been both enlightening and thought provoking. It has not been so long, in fact just a few years ago, since most steel men's definition of a protective relay was: A piece of apparatus which could be shorted out in an emergency.

In those early days relays consisted of a single solenoid and a plunger with contactor, with or without time delay. These relays, simple as they were, gave good service and were ample protection to the elementary steel mill power systems of that day.

However, as the steel mills grew so naturally did the power systems. These systems grew not only in size, but also in complexity, and for many reasons, such as economy (saving in copper), flexibility, regulation, and most important of all continuity of power supply, it became necessary to operate them in various combinations. But these simple relays could not tie into the scheme of things; they were inadequate; they were not discriminating; they could not be operated in series nor parallel, nor in a ring. To operate in this way without selective and directional relays is practically impossible.

It is pleasing to note that more attention is being given to relaying, with a subsequent reduction in outages and much less destruction when trouble occurs.

A thorough understanding of the principles underlying the application of protective relays is previously dependent upon a knowledge of the behavour of short circuit currents. For the application of relays as a system expands, and for the proper setting of all relays, it is essential that every large steel mill should have at least one engineer well versed in the calculations of short circuit currents.

The differential protection of high voltage rotating apparatus has become standard practice. The practice of differential protection for transformer banks has not as yet become accepted in some areas, the reason for this is that transformers are a static type of equipment, and are not subjected to the possible number of faults which rotating equipment has. However, such protection is really a good investment when considering that many transformer banks are the bottle neck of power in-flow to important areas. The quick disconnection of a bank caused by an internal fault of one transformer can save the other two for open delta operation, should there be no spare transformer on hand.

Older steel mill installations were built without neutral being grounded and in many cases these systems are still in operation. Neutral grounding with a limiting resistance is of course desirable. It is difficult to even hazard a guess how much trouble is caused by arcing grounds, but certainly some of the insulation break-downs suffered in steel mills are nothing more than this fault.

There has been a revival of interest in the use of Peterson coils, that is if one judges from the number of articles printed upon the matter. I would like to know what the economical advantages are which justifies the installation of a Peterson coil on an ungrounded system rather than change the system over to a grounded neutral?

Economy demands that all generating equipment be tied together into one network, and that this power be generated with a minimum number of units. The inter-connection of all power generation into a single system is a great advantage, giving a more uniform

load condition, and insuring the proper characteristics of power at the point of utilization.

Some steel companies already have their distribution system for widely scattered plants tied together. The economy of this arrangement has a wide appeal for the trend in that direction is getting more and more each year.

The steel mill power demand still continues to grow. There are several general applications which are becoming more important in this demand for additional power: such as industrial heating, tempering and annealing furnaces of the electrical type. These demand a thoroughly reliable distribution system for the static and transient load conditions.

In order to have this kind of a distribution system, as Messrs. Bancker and Kaufman have so ably pointed out, it is essential to have a well planned relay system and to keep it up with adequate maintenance.

M. H. MORGAN, JR.: I would first like to express my appreciation to both the program committee and the authors for an able presentation of a pertinent subject.

I have come to depend on this Association to select from current engineering developments those which are of definite use to a mill engineer and to present from time to time a summary of the information I need to apply those developments to steel mill engineering, and I find upon examination of this paper that my expectations are fully realized in this instance. I would add very little to the paper as presented.

Because of the nature of their duties, including as it does, the care of a great many different kinds and character of equipment, typical steel mill maintenance men must of necessity be jacks-of-all-trades rather than relay specialists or specialists in any line. Therefore, of various relaying schemes which may be considered for a given job, it is the simpler and perhaps cruder device which will likely give better performance than the one which requires more exact adjustment and more expert care. Finally, it is seldom possible under mill conditions to locate relays in a clean place and under the atmospheric condition which obtain the relay proper, must, to be reliable, include an enclosure which will be and will remain dust-tight and preferably gas tight. I note that the development of new devices of this character include such provisions.

I would like to endorse most heartily the author's suggestion concerning periodical examination of a growing system on the short circuit calculating board. It has so often happened that a steel mill 6600 volt distribution system has grown by simple additions of loads and generators until the concentration of capacity reaches such a point that a fault on the system will have devastating effects on both equipment and service. Something radical and quite expensive must then be done to avoid blowing up breakers and to reduce the frequency and extent of system outages, whereas a short circuit study at an earlier point in the development of the system would have led to better design and sounder growth.

The simple and thorough way to study the problem of an addition to or rearrangement of an existing system is to set it up on the calculating board and see there for yourself the magnitude and extent of effects and faults on it at any point. It is then possible in a few minutes time to rearrange your system as set up on the board to include any corrective scheme which may be suggested and test the performance of the rearranged system thoroughly so that whatever means is finally adopted, is not only effective but is the best for your particular condition.

In selecting or discarding alternate schemes, it is necessary that the person making the study know a great deal about the system, such as—which feeders or tie lines must always be closed in, relative importance of different loads and loading and operating power factor of various parts of it and other characteristics peculiar to that system alone, otherwise he will not arrive at a thoroughly satisfactory and effective solution. Let me suggest, therefore, that you yourself be on hand, looking over the engineer's shoulder when he sets up your system on the board, and that you take the few hours necessary to consider and test out on the board various alternative schemes rather than send off a diagram of your system for study. Because, be that engineer ever so conscientious and capable, he cannot know enough of your local condition to prescribe the most effective solution and, incidentally, if you do go through the study yourself in this comprehensive manner, you will get personally from it an understanding of the possibilities and shortcomings of your plant system which I believe can be obtained in no other way.

J. W. BATES AND W. E. WINTERHALTER: Mr. Bancker's and Mr. Kaufmann's paper on the use of relays and adequate design consideration to insure uninterrupted power supply to steel mills is fittingly adapted to focus attention on the many aspects of this branch of engineering. There will undoubtedly be occasion to rely more and more on every phase of protection available, as large mills comprised of many closely coupled electrically driven units go into service—as investments in electrical equipment increase—as power costs become a more significant item of production expense and make economies of large scale generation and transmission attractive.

As an electric power consumer, the steel industry is fortunately situated. Its concentrated loads, opportunities to schedule and control demands, to utilize otherwise wasted heat from processes, and to combine generation of steam for power and processing afford advantages inaccessible in many other fields of power consumption. However, these same advantages impose exacting requirements upon protective systems, of which relays are the nerve center. Concentrated loads, control of demand, and efficient use of heat energy dictate a heavy interconnected system in which equally heavy short circuit currents cannot be entirely avoided.

As Mr. Bancker has pointed out, relays are a part of a system which protects by isolating circuits which develop faults, from the rest of the system. High speed isolation of high current short circuits is one of the most practical methods of insuring against impaired service quality, damage to equipment, and spreading of arcs to other circuits.

Many of the primary lines in steel mill systems are short, less than a mile long. It is frequently difficult, and sometimes impracticable, to apply existing de-

signs of directional and impedance relays so that they can be depended upon to select between faulted and clear lines on this type of system.

Mr. Kaufmann has called our attention to methods of incorporating resistors and reactors in sytem designs to limit fault currents and minimize voltage dips due to these currents, without introducing high voltage regulation during normal system operation. Suitable resistors and reactors installed between the system neutral and ground can limit line to ground fault currents to the order of normal load currents.

As a rule, a high percentage of all faults on a grounded system start with an insulation breakdown from line to ground. The advantage of having relays sensitive and fast enough to positively detect these low current faults, before a high current phase to phase fault develops, is apparent. Overcurrent ground relays fill these requirements for many, but not all, locations.

Practically every general type of relaying is being used to protect steel mill systems, including some d-c pilot wire for relatively long lines. However, all things considered, alternating current percentage differential pilot wire relaying is definitely established, in our present day practice, as the closest approach to the ideal basic relaying for short lines of heavy distribution systems serving steel mills. It combines speed, selectivity, and sensitivity. Pilot wire cost is reasonable for these short lines and no potential supply is required. This type of relaying is closely related to differential relaying that has long been a first preference for detecting faults in machines and transformers. This facilitates application of "overlapping" to protection of lines, buses, transformers, and machines to effect uniformly prompt isolation of all types of faults with minimum disturbance to the serviceable part of the system.

Reference to "overlapping" protection suggests a general protection requirement that is important; regardless of the character of a system or the type of relaying applied to it—this being, "Complete coverage of all circuits, buses, and equipment—for all operating conditions". Most of us have observed extensive damage and service interruptions caused by failure to completely cover a bus, low capacity circuit, or an equally inconspicuous element of a system.

From many years experience with overcurrent relays, we know that the number of locations where these relays can meet present day basic relaying speed, selectivity, and sensitivity requirements is limited. However, this type occupies a prominent place in the field of "back-up" protection, principally because it is simple, reliable, and inexpensive.

Opinions differ widely regarding how much speed, selectivity, and sensitivity demanded in basic relaying can be discounted in selection of relays for a "back-up" system. The inherent selectivity so desirable for basic relaying, and which permits relay operation for faults in one circuit only, precludes the use of the breakers of adjacent circuits to back-up the breaker normally controlling a line or equipment. Some discounting of selectivity is, therefore, not only permissible but desirable, because relays are not more likely to fail than breakers or their auxiliary equipment.

When the protective equipment of an adjacent circuit is depended upon for "back-up", its operation should be delayed long enough to give the basic protection an opportunity to operate. Equivalent sensitivity is desirable and available in many cases for detecting line to ground faults, but the most prevalent attitude seems to be that it, as well as speed and selectivity standards considered most essential for basic relaying, can be discounted considerably in selecting "back-up" relaying.

Sometimes the need for any "back-up" protection at all is questioned. That it is necessary seems to be the firm conviction of many system operators and engineers, even though the "back-up" protection, which can be economically justified, may associate localized service interruption with its operation to isolate the few faults that basic protection fails to clear. Too much recognition cannot be given to the fact that the number of times "back-up" protection will be required to operate will vary inversely with the number of fault prevention features incorporated in system design, and the care exercised in selection, adjustment, maintenance, and testing of the basic relay system. Today most steel mill maintenance departments maintain and test relays thoroughly, but it may be well to emphasize the desirability of testing, as a unit, the protection system provided for fault isolation.

If the final installation test does not include the combined protection unit of relays, breakers, and transformers used to represent primary circuit conditions to the relays, results are apt to be disappointing. Satisfactory check tests can usually be made with indicating and recording meters found in our testing departments, also, in most cases, "staged tests" are more satisfactory for this purpose than attempts to observe faults incident to system operation.

Current limiting reactors installed in phases for bus sectionalizing, and to partially isolate relatively small feeders from a heavy system, are especially useful in limiting fault currents, where large induction and synchronous motors represent a high percentage of the total load, as is the case in steel mill systems. Mr. Kaufmann has suggested that flow of load current through sectionalizing reactors, and consequently voltage regulation of feeder buses, can be reduced by proportioning normal power supply to, and load of, the individual feeder bus sections as equally as possible. When supply of appreciable load current through sectionalizing reactors cannot be avoided, voltage regulation can be minimized by transferring only high power factor load through the reactors.

Although Mr. Bancker and Mr. Kaufmann have very properly devoted the major part of their paper to relays and equipment associated with them to provide "protection by isolation", we cannot afford to overlook the possibilities of "protection by prevention". In analyzing the relative merits of these two classes of protection, we find that the only justification for isolation is that it is not practicable to justify 100 per cent dependence upon preventative measures, such as:

(1) System neutral grounding to provide insurance against normal frequency overvoltage and arcing grounds. System grounds should be made at every source of power supply that can

carry the system, or some section of it, alone.

(2) Use of underground construction to avoid exposure to lightning voltages, wind, sleet, and accidental contacts.

(3) Application of lightning arresters, surge capacitors, and ground wires to overhead lines, outdoor substations, transformers, and machines, in order to reduce a high percentage of lightning, and other transient voltages appearing on circuits, to below the impulse strength of insulators and equipment insulations. In connection with these applications, too much emphasis cannot be placed upon the necessity for low impedance ground connections for lightning arresters, surge capacitors, and tower footing grounds. If these are not available through use of multiple ground rods, plates, or coils installed in permanently damp soil, resort may be had to the use of counterpoise grounding, which has passed beyond the experimental stage.

Provision of preventative protection, like protection by isolation, is readily recognized as a function of system design and requires careful consideration in regard to effective application and cost. Operating records show that the frequency of fault occurrence can be reduced as much as 75 to 90 percent, through relatively small investment in this class of protection.

WRAY DUDLEY: Not having had opportunity to examine the papers, I am not prepared to discuss them in detail, but I feel we are indebted to the two authors for a very complete discussion of an important subject which the average steel mill engineer is not liable to come in contact with more than once or twice during his active life. Naturally he becomes very rusty on the question of relay protection and operation, and when he is suddenly confronted with the responsibility of protecting his high voltage system he is usually at a loss to know how to proceed. The information here presented will doubtless be referred to many times in the future.

Referring to the table exhibited by Mr. Kaufmann, which indicated magnitude of short circuit forces in a system of a given capacity with increasing voltage, I noted that his comments did not extend to the 13,200 volt range and would like to ask if the decreased stresses which it would insure justify, consideration of the higher voltage range for steel mill feeder lines.

E. L. HARDER: You have listened to an excellent general perspective of the problems involved in providing reliable power supply to steel mills. The same principles are, of course, applicable in other large industrial installations or central stations. It is significant that in discussing the protective relaying it has been necessary to go into considerable detail in the system design. The two go hand in hand. Adequate relay protection is a vital factor of system design and also to obtain adequate protection, a system must be laid out so that faults can be promptly located and cleared without undue shock to the rest of the system.

It will be of interest to know just how frequently faults occur on power systems. Experience on one extensive 110 kv. system over a period of several years indicated about one disturbance per 10 miles of line per year and on this system lightning accounted for 56 percent of all the disturbances. Of the other 44 percent of disturbances there are only three that are large enough to call specific attention to. One of these is sleet, wind and jumping conductors accounting for a little over 12 percent. The second is apparatus failure accounting for 9.4 percent and the third was due to closing in on a fault, accounting for 11.4 percent of the disturbances. The latter is a necessary evil as reclosures are successful in a large percentage of the cases and the gain in system operation from following this procedure exceeded the disadvantages. Of course, this 11.4 percent includes unintentional closing as well. That covers all but 11 percent of the disturbances which are due to miscellaneous causes. Thus, instead of protecting against some mysterious monster that jumps on the transmission line we are actually protecting against definite known factors that occur with fair regularity.

It would also be of interest to know that on this particular system the protective relays performed the correct function in 92.2 percent of the cases. Of the remaining 7.8 percent the relays did what they were set to do in 5.3 percent of the cases even though the action resulting was undesirable from the standpoint of system operation. This is a matter where the system design comes in, as factors in the design frequently make it impossible to provide 100 percent selectivity in relay action, particularly under the emergency operating conditions. There were 2.1 percent of the cases in which the protective system as a whole including the relays and current transformers and the circuit breakers misbehaved, and only 0.4 percent of the cases in which the relay failed to operate to clear the fault when it should have. This data includes a total of nearly 1200 disturbances over a period of four years and involved 2800 relay operations. It is characteristic of the operation to be expected in practice with properly applied and maintained relays.

Another feature of general interest is just how fast things happen when a fault comes on a system, what speed is necessary in circuit breakers and protective relays in order to avoid serious consequences, and how good a job the available equipment will do in producing the necessary speed.

Faults on a power system are a whole lot like blood poisoning in a human being. When they occur the trouble spreads out rapidly and it is just as necessary to remove the affected part without any delay.

First, let us establish a time measure that we can sense. Most watches tick five times a second so that each tick is 2/10 of a second or 12 cycles on a 60 cycle basis. Now the fastest relays work in about one cycle and the standard breaker speed is 8 cycles. Then with high speed differential protection and 8 cycle breakers the fault is cleared in less than the time between two successive ticks on your watch, which time we shall call "one tick".

With high speed distance relays, where lines are long enough to apply them, most faults will be cleared just as rapidly, but some, in the end zones will require time delay in selectivity, which will run the total clearing time up to about 25 cycles or 2 ticks. Listen to your watch say "tick, tick, tick". The first is the

fault, the second is the 1st breaker opening and the third is the final clearing.

Over current relays may be anywhere from instantaneous (one cycle or less) up to 2 or 3 seconds, with several selective time settings each one ⅓ to ½ second longer than the preceding one.

As to effects on motor operation and machine synchronism, it will be appreciated that ill effects vary with fault intensity from least effect with line-to-ground faults on high impedance grounded systems to greatest effect with solid 3 phase faults. Line-to-line and two-line-to-ground faults are intermediate in that order. In any event, the effect is measured roughly by the average reduction in line-to-line voltages of the three phases. A large synchronous motor operating near full load, with an average strength of system connecting it to the power source, will remain operating in synchronism if the average voltage at the terminals drops to 60 to 70 per cent for not over 2/10 seconds or one "tick". The transient torque during the first quarter second after the voltage drop is much greater than the sustained torque at the same voltage. Induction motors do not pull out of step. They simply slow down and can stand considerably longer low voltage periods without drawing excessively high current when the voltage is restored to normal.

While conditions vary widely it is evident that time reductions available from slow to fast fault clearing arrangements are in the range where resulting improvements in operation are to be expected. Individual plant problems of this nature may be studied analytically or on the a-c. network analyzer (calculating board) to determine the fault clearing speed necessary.

E. H. BANCKER: In the discussion there was, I believe, just one question asked concerning the application of Peterson coils to steel mill power systems. Also, during the discussion, Mr. Winterhalter mentioned the use of protective devices such as lightning arresters. It might be advisable to review briefly the position relaying has in protective measures and at the same time answer the question concerning the Peterson coil. There are three methods employed in protecting service continuity. The first is to prevent faults from ever happening; the second lets it happen but renders it harmless; and the third lets it happen and disconnects the faulty area quickly enough to avoid severe disturbance to the remainder of the system. Lightning arresters, ground wires and similar measures belong in the first class. Petersen coils and expulsion gaps occupy the second position. Relays are the last court of appeals and their function begins only when some of the other measures have failed. The Petersen coil is useful in those applications where the majority of system faults are transient one wire to ground contacts. This is a condition normally prevailing where lightning is the major factor in causing faults.

The Petersen coil is merely a neutral grounding inductance that supplies to the system a fault current as nearly equal and opposite in sign to the capacity current which would flow at the point of fault on an ungrounded neutral system. The resultant of these two currents is a very small unity power factor fault current which is self-extinguishing. A system provided with Petersen coils never even experiences a dip in voltage between phases when a one conductor-to-ground fault occurs.

It is very widely used in Europe, especially in Germany. Almost all Japanese power systems also employ Petersen coils. In the United States its application has only recently gotten well under way. The probable reason for the earlier adoption in Europe and Japan lies in the fact that the prior practice of these countries was the operation of systems with the neutral ungrounded. In the United States a great majority of utility power systems have had grounded neutrals and it was too much of a mental hurdle to consider what seemed such a radical step as inserting a high reactance between the system neutral and ground.

Petersen coils probably have but little utility in industrial power distribution systems because it is much less likely that there will be transient contacts between one conductor and ground. The Petersen coil is of no use in a cable system or in connection with apparatus failure since it is only effective where the broken down insulation is self-healing, like air. In Europe it actually is used in cable systems, but operating practice there permits continued operation with one conductor grounded until the point of ground is located and a convenient time arrives for disconnecting the defective section. Such operation does not seem to be acceptable to operating engineers in the United States.

A Petersen coil installation cannot tell where a fault lies. Hence, in the case of permanent faults, it has been the usual practice in this country to solidly ground the system neutral after a minute or two of flow of ground current through the coil. This, then, enables protective relays to select the section containing the fault.

One of the discussors mentioned undervoltage devices and this is a point that seems to need continual emphasis. Many so-called interruptions in industrial plants are nothing but the dropping out of instantaneous undervoltage devices where the voltage is reduced by a fault somewhere on the system. The fault may be cleared quickly enough so that there is no reason why the motors should not have continued in operation as soon as the voltage reappeared and yet they shut down just because the undervoltage devices dropped out. It seems necessary to have a continuous campaign of education to induce users to supply time undervoltage devices instead of instantaneous undervoltage devices. If this practice became more universal, "many an interruption" would be avoided. Obviously, no system can be economically constructed so that it will never have a short circuit. Therefore, it is necessary to resort to some such expedient as time undervoltage devices to distinguish between a real failure of voltage which should not cause restarting when voltage reappears and the momentary dip in voltage that lasts for the duration of short circuits.

In conclusion I should like to convey my appreciation to the audience for the very courteous discussion, which may perhaps be ascribed to the fact that the subject under discussion is not controversial.

R. H. KAUFMANN: There is one additional point concerning the use of Petersen coils in general industrial distribution systems which might bear mentioning. The application of Petersen coils to general industrial distribution systems is subject to limitations not encountered in transmission systems of fixed extent. The Petersen coil functions to neutralize line-to-ground fault current by supplying a lagging current equal in magnitude and directly opposing the leading charging current of the electrical system to ground. For effective results, these two quantities must be approximately equal. In the usual industrial distribution system, load machines and secondary feeder circuits are being continually switched on and off the system and each such switching operation changes the total charging current of the electrical system. To maintain balanced compensation from the Petersen coil would require that the reactance of the latter be adjusted correspondingly, and this constitutes a severe limitation. It is very difficult to acquire a means of assuring that the Petersen coil current is in approximate agreement with the system charging current to ground.

Upon the occurrence of a line-to-ground fault which is not self clearing and in view of the multitude of individual circuits involved in the usual distribution system, it would probably be advisable or necessary to supplement the Petersen coil with auxiliary equipment, which in such an instance would temporarily ground the system neutral to accomplish isolation of the ground fault from the system. Unless this supplementary equipment is incorporated, the presence of such a sustained ground fault would allow the entire electrical system to continue to operate with a fully displaced neutral—i. e. with full line-to-line voltage between each of the two unfaulted line conductors and ground. Incidentally, it would also demand that the Petersen coil be designed for continuous current flow.

A distribution system in which the primary electrical system is of substantially fixed extent with transformers at the supply and receiving terminals would be well adapted to the application of a Petersen coil if the line-to-ground charging current is several amperes or more.

Use of 13.8 kv. Industrial Systems

The selection of operating voltage is governed primarily by overall economy. In steel mill systems, it has been generally possible to distribute and utilize a large portion of the total power at a common voltage. Where local generation is involved it has also been possible to generate at this common voltage. In this manner, for the major part, the necessity for voltage transformation is avoided.

Up to the present time, the use of 6600 volts has adequately accommodated the largest systems. At this voltage there is little increase in price or deficiency in performance of generating units and the larger size load units. No severe difficulties in power transmission or switching equipment need be encountered if individual generating units are not in excess of about 30,000 Kva.

At 13.8 Kv. it would be expected that the price increase in generating units would be quite moderate for units of 20,000 Kw. A rather marked increase in price of load equipment designed for operation at 13.8 Kv. would be expected. It would also be expected that a large group of motors whose unit size ranges between 300 and 1000 hp. would not be adapted to a reasonable design at 13.8 Kv. but could be built for 6600 volt operation. The use of 13.8 Kv. for distribution would require that step-down transformers be included to accommodate this group of machines.

It would not be expected that any material reduction could be made in the switching equipment costs.

A considerable reduction in the cost of the distribution circuits proper could be attained at the higher operating voltage. However, to realize better overall economy requires that the saving in transmission costs retain a positive balance after deducting the increased cost of load equipment, generating equipment, additional transformers as may be necessary, and making correction for the capitalized value of difference in losses.

In distribution systems typical of steel mills where a large portion of the load equipment can be operated directly at the distribution voltage, it would be unusual to be able to justify 13.8 Kv. operation.

In large capacity systems distributing power to relatively small load units which are not suited for voltages in excess of 2300, voltage transformation at the terminal end cannot be avoided in any case, and in such instances the use of 13.8 Kv. on the primary system may show real economy.

BAILEY DISCUSSION

(*Continued from page 31*)

limit to the amount that can be added and this limit is determined by the furnaces which feel the effects first. Around 500 Btu. is probably as low as one can go. However, the scheme does help one out of fuel shortage difficulties and on a good many furnaces the effect of mixing is hardly noticeable.

In answer to Mr. Gumaer's question—the cleaner blast furnace gas is the better. Orifice plates, butterfly valves, etc., have to be kept clean to give the best results. We have walked through our mains after several years of operation and found relatively little dirt in them. No serious troubles from freezing in the mains has been experienced.

No experience has been had in mixing coke gas and natural gas as the latter fuel is not available.

In answer to Mr. McDonald's question no attempt is made to continuously meter the blast furnace gas to stoves and boilers as this gas is only partially cleaned.

Answering Mr. Conway's question, tests were made some years ago on open hearth furnaces using blast furnace gas to atomize coal tar. The results were disappointing and bear out statements by Mr. Fisher and Mr. Leahy that no satisfactory substitute for steam atomization applied to open hearths seem to have been found.

MESTA
WORKING ROLLS
FOR FOUR HIGH HOT MILLS

MOLYBDENUM CHILL GRAIN
NICKEL GRAIN NICKEL CHILL MESTA HARDENED CHILL
MESTA HARDENED GRAIN MESTA SPECIAL ALLOY STEEL

MESTA MACHINE COMPANY
PITTSBURGH, PA.

NEW SKIN PASS MILL AT GREAT LAKES

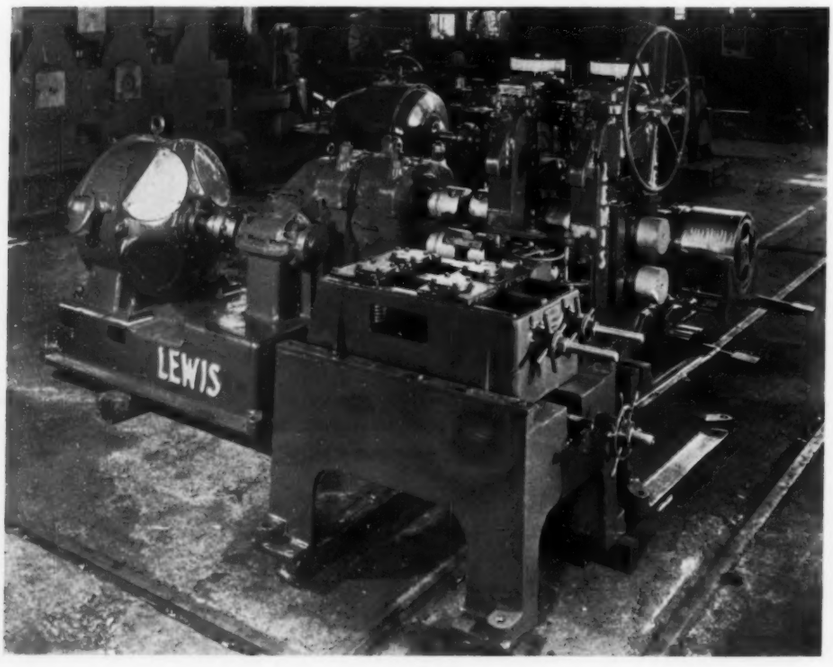
▲ Installation of a skin pass mill with an edging stand and a tension coiler, built by Lewis Foundry & Machine, Division of Blaw-Knox Company, has been completed at the plant of the Great Lakes Steel Corporation. The mill is an 8 inch diameter by 10 inch face two-high unit, to be used for skin passing cold slit strip in sizes from ½ to 6 inches wide and .012 to .125 thick.

The units are all roller bearing equipped throughout, and capable of rolling speeds of 400 to 1200 F.P.M. A 40 H.P. motor, 400 to 1600 R.P.M., supplies the motive power, driving through a flexible coupling to a combination gear drive and pinion stand and then through universal spindles to the mill rolls.

Two of the vertical rolls in the edger are fixed while the other two are adjustable for strip widths. The next of four vertical rolls is also adjustable for the face of the skin pass rolls so that the work is spread over the complete roll body.

The coiler is of the collapsing drum type, driven by a 20 H.P. motor. An air operated clutch provides for uniform coil build-up, that is, for maintaining the tension on the strip as the coil builds up on the winding reel.

The unit is housed in cast steel, and the rolls are of forged alloy steel hardened to 90 scleroscope. The illustration shows the unit while still in the shop with the vertical edger in the foreground.



Two-high 10″ skin pass mill with edging rolls and tension coiler for rolling cold slit strip.

CONTINENTAL STEEL ADDS TWO MILLS

▲ Completing a three year modernization program, the Continental Steel Corporation has recently installed a three-high jump mill at its plant in Canton, Ohio, and a three-high balanced mill at its Kokomo, Indiana, plant.

Both mills employ rolls 62″ in length, 32″ in diameter for top and bottom rolls, and 20″ in diameter for the middle roll, and are equipped with tilting type feeder and catcher tables. The jump mill is designed to roll sheet bars 10″–16″ wide, with a maximum length of 52″ and a maximum thickness of 9/16″, which can be reduced to 18–22 gauge in five passes. The balanced mill is designed for roughing sheet bars 8″–16″ wide, in lengths up to 52″ and thicknesses up to 1¾″. This mill employs a pneumatic type of balance, and is provided with a pre-set control usually operated on two single passes and three matched passes.

An interesting feature of the balanced mill is the method used to

drive the top roll, wherein a friction pinion is used, employing friction discs which are mounted within the pinion.

The mills were built by Continental Roll and Steel Foundry Company.

Lubrication of the mills is effected by forced pressure feed systems supplied by Farval Corporation.

Motors for the equipment in this development were furnished by Reliance Electric and Engineering Company, except the two screw-down motors on the balanced mill, which were supplied by Westinghouse Electric and Manufacturing Company. Motor brakes for feeder and catcher tables and for screwdowns are from Electric Controller and Manufacturing Company, while the entire control equipment was furnished by Clark Controller Company.

Two pair furnaces 80 feet long by 62 inches wide, with a nominal capacity of 11 tons per hour each, as well as a 60 foot double pack furnace were installed in connection with this improvement. These were supplied by the Wean Engineering Company, as were mechanical tables, a wheelabrator, doubler, etc.

Conveyers used in conjunction with the new equipment were furnished by Mathews Conveyer Company.

NEW TYPE OF LUBRICATION SYSTEM

▲ Blaw-Knox Company, Pittsburgh, Pa., through its Gordon Lubricators Division, announces a new line of grease lubricating equipment offered to users of cranes and auxiliary equipment. It is known as the Model H Lubricating System, and contains a manually operated pumping unit designed for use with the new Model H measuring valve.

The pump holds eight pounds of grease and can be filled by hand, or by means of a portable grease pump through a fitting provided for that purpose. Double acting pistons, a unique feature for pumps of this type, reduce the time cycle of operation, and a detachable handle is a safety precaution against tampering or excessive operation. Other normal equipment includes a control valve, a grease strainer, and a pressure gauge.

The Model H valve operates on a simple displacement principle. The springs used are compared in their action and design, to the valve springs used in automobile engines. The line pressure from the pumping unit is utilized in forcing a measured shot of grease into the bearing, and when the pressure is relieved at the pump the valves recharge in readiness for the next greasing cycle. Each valve operates as an independent unit although lubricating blocks may be made up in multiple feed groups of as many as four valves. Each valve has an indicator which gives positive evidence of a charge of grease being delivered to the discharge line.

This auxiliary equipment system adheres to the Gordon Lubricators' principle of single line operation, which is similar to that of a community water line system, and provides independent operation of all valves in parallel. While centrally motivated, each valve is adjustable as to quantity of grease, being capable of feeding from 0 to 0.4 ounce per shot. Economy from an installation standpoint is claimed because of the combination of single line piping and multiple feed mounting, and the individual adjustments are designed to provide operating economy.

ARMCO PLACES FIFTEEN NEW COKE OVENS IN SERVICE AT HAMILTON PLANT

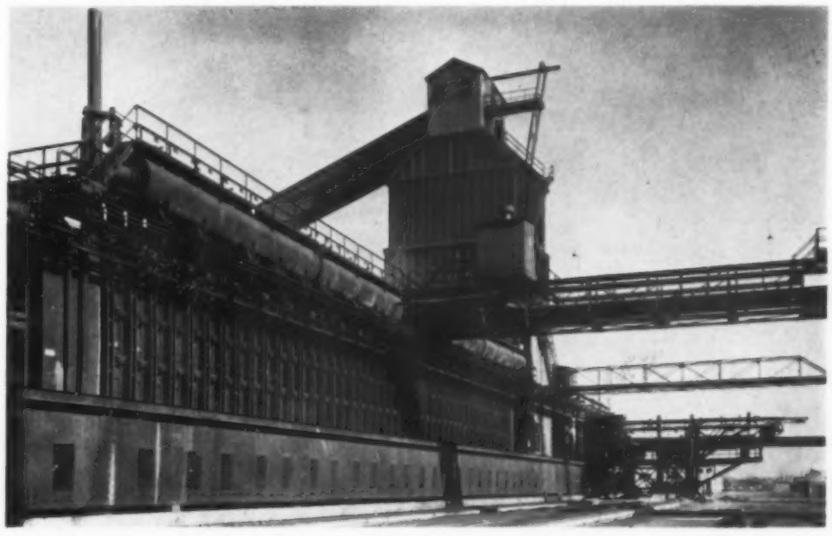
▲ Fifteen low-differential, underjet, basement-type combination Becker Coke Ovens were recently placed in operation at the Hamilton, Ohio, coke and iron plant of the American Rolling Mill Company.

Each oven has a capacity of 622 cubic feet, is 40′–8″ long between doors 12′–6″ high, with an average width of 16″, and will hold approximately 15.5 tons of coal. The maximum output of coke is about 27 tons per oven per day.

As the Armco plant at Hamilton already operated 45 ovens, the number at the plant will now total 60. About 1500 tons of coal will be charged into them each day. After coking, this will yield about 100 tons of coke, 10,000,000 cubic feet of gas, 12,500 gallons of tar, 15 tons ammonium sulphate, 3200 gallons motor benzol, 510 gallons toluol, 175 gallons xylol, and 50 gallons solvent naphtha.

The new addition is the first installation of this type of large capacity ovens in the United States. It embodies many improvements. All reversing equipment is placed in a basement-like structure below the ovens. This facilitates operation and inspection and improves working conditions for the men.

In addition to the ovens, other new



Fifteen low-differential type Becker ovens were added at the extreme end of this battery.

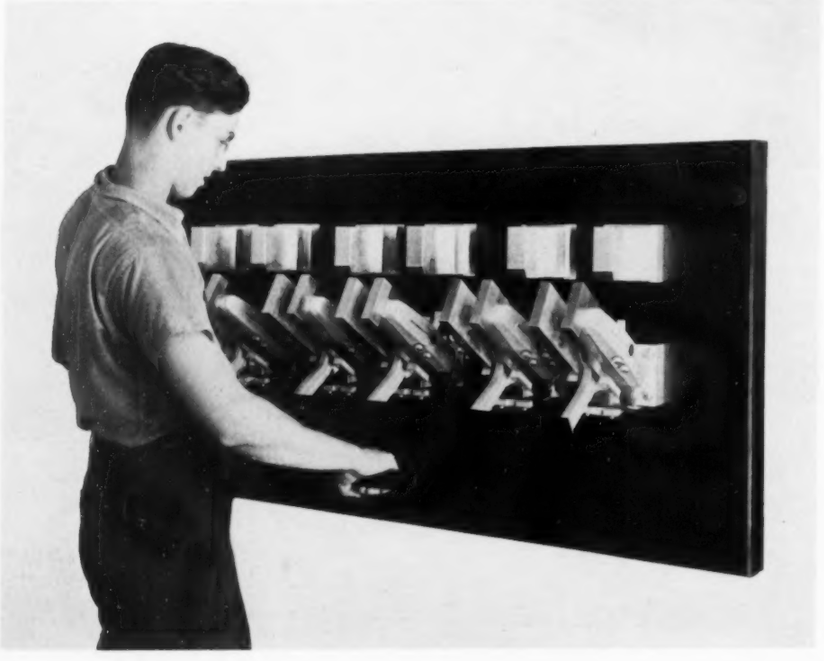
equipment has been installed to make operation of the plant more efficient.

The lighting of the new ovens is in anticipation of the blowing in of the second Armco blast furnace at Hamilton at a later date. This blast furnace was completed last year. The plant not only supplies hot pig iron to the Armco open hearths in Middletown, but manufactures all grades of merchant iron for foundries.

NEW TYPE THREE-POLE DISCONNECT SWITCH

▲ The I-T-E Circuit Breaker Company of Philadelphia, Pennsylvania, has recently completed a hand-operated, three pole, 10,000 ampere disconnect switch. This switch is so constructed that all three poles are opened or closed in unison, thus constituting, in effect, the opening or closing of a 30,000 ampere, single-pole switch. Contrast the ease with which this huge switch is manually operated and the effort required to operate a conventional type knife switch of one-quarter the amperage. This singular engineering achievement which enables a switch of such high capacity to be operated by hand is incorporated in the patented "Klamp-Tite" feature.

Three-pole hand-operated Klamp-Tite disconnect switch for 10,000 amp., 250 volt d-c service.



Sectionalizer, enclosed in tight cabinet, for isolating parts of power systems.

SECTIONALIZER FOR POWER FEEDERS

▲ The Electric Controller and Manufacturing Company of Cleveland, Ohio, announces the new Line-Arc Repeating Sectionalizer. Consisting of a magnetic contactor of Line-Arc design, an overload relay equipped with ratchet lock-out feature and a timing circuit to provide time delay after the overload relay has tripped and opened the contactor due to overload, ground or short-circuit. The enclosing cabinet is of drip-proof design and can be furnished gasketed, dust-tight, water-tight, or other form as required. Mounted on the side of the cabinet are an "on" and "off" push button for closing the magnetic contactor and a button for resetting the ratchet lock-out feature of the over-load relay. The equipment illustrated is equipped with a ratchet feature giving a maximum of six operations before the contactor is definitely locked open. The ratchet can be easily adjusted to provide from one to six operations as desired. Provision is made to lock the push button circuit open.

Applications for this new development may include protection of power feeders serving cranes or crane runways and other types of circuits in which it is desired to isolate only part of a power system upon occasion of overload or short circuit.

MOTORS FOR SEVERE DUTY CYCLES

▲ Type CS hoist motors, designed for severe intermittent service where frequent starts, stops and reversals are encountered, and especially applicable for hoist service and also as door operators, auto lifts, gate valves, blast furnace mud guns, and car spotters are announced by Westinghouse Electric & Manufacturing Company.

The high resistance rotor provides the highest ratio of starting torque to starting current obtainable with a squirrel-cage motor. They cause minimum disturbance to the line and permit the use of a low cost full voltage starter on the majority of installations. They handle light loads quickly while heavier loads cause the speed to decrease with a corresponding increase in torque.

Type of motor designed for severe intermittent service, with frequent starts, stops and reversals.

Ball or sealed-sleeve bearings can be furnished specially designed both to exclude dirt and foreign particles and to prevent loss of lubricant. They can be built with special mounting brackets such as NEMA class "B" flanges, faceplate brackets and with one or both brackets omitted for those built-in applications where the frames are bolted directly to the driven machine. The frame is cast in one solid piece with feet cast integral providing an exceptionally strong rigid design especially suited to withstand heavy overloads and frequent reversals without distortion.

GAGE FOR VERY HIGH PRESSURES

▲ A power type pressure gage suitable for the measurement of extremely high pressures and accurate to one-tenth of one per cent of the reading, has been developed by Bailey Meter Company, Cleveland, Ohio. This gage provides accurate pressure readings on an indicating scale and may also transmit these readings to indicators and recorders located at distant points.

The pressure to be measured is applied to a small pressure piston which supports a pilot valve and a table loaded with removable weights. A small motor serves to rotate the pressure piston and pilot valve, a

FARREL ROLL CALIPERS

Give Exact Check of Roll Accuracy

Uniformity of gauge of rolled strip and sheet depends upon the precision with which the rolls are ground. Accuracy of roll shape can be most easily checked with a Farrel Indicating Caliper, an indispensable instrument wherever roll accuracy affects the quality of output.

The Farrel Caliper measures the variations in roll diameter and the amount of crown, concavity or taper. With it, roll accuracy can be checked against predetermined standards quicker than in any other way and to finer degrees of accuracy. Readings may be taken at any point along the face of the roll.

The Caliper is simply constructed, light of weight, easy to handle, and is designed for permanent accuracy. It moves freely on rollers, requiring only a finger touch to traverse it along the roll.

Rolls can be checked in a fraction of the time required to test them by other methods; it eliminates the inaccuracies traceable to the human element in the use of those methods; it gives identically the same reading on repeated trials.

Farrel Roll Calipers are made in five sizes to measure rolls from 4″ to 50″ in diameter.

Descriptive circular giving complete details will be sent on request.

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FARREL-BIRMINGHAM COMPANY, Inc.
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all bearing being provided so that the removable weights and weight platform need not rotate. The motor also drives a small oil pump which provides hydraulic pressure for operation of the power piston which in turn moves the mercury cup, the indicating pointer and the selsyn motor for electrical transmission of readings.

For each pressure applied to the small rotating pressure piston, a definite position of the power piston, mercury cup and indicating pointer is obtained. Gages operating on this principle have been built for suppressed ranges and extremely high pressures.

NEW LITERATURE

▲ Lukens Steel Company, Coatesville, Pennsylvania, has issued a new bulletin entitled: "Methods for the Fabrication of Lukens Nickle-Clad Steel". This interesting and informative booklet gives a good description of the various methods of fabrication. Complete with pictures and tables illustrating processes of welding of nickel to steel, this book may be obtained by writing to Lukens Steel Company and requesting Bulletin No. T-4.

▲ Lincoln Electric Company has published a new bulletin describing procedures for producing all types of welds in mild steel, for welding all metals used to any extent industrially and for applying surfacing metal to meet any type of wear-action in service.

Anyone desiring this attractive thirty-six page brochure should write to the Lincoln Electric Company, 12818 Coit Road, Cleveland, Ohio, requesting Bulletin 401-A.

▲ Askania Regulator Company recently issued a bulletin on "Automatic Control for Steam Generating Units". Principles and applications are given in this booklet which describes automatic boiler controls. Askania Regulator Company is located at 1603 South Michigan Avenue, Chicago, Illinois.

▲ Combustion Engineering Company, Inc., has published a new thirty-six page bulletin: "C-E Direct Fired Systems for Burning Pulverized Coal". It contains a synopsis of the development of pulverized coal firing and its influence on the capacities and designs of steam generating units.

Requests should be directed to the Combustion Engineering Company, Inc., 200 Madison Avenue, New York.

▲ Elwell-Parker Electric Company has published a bulletin on the "IZ Load Carrier Truck". This new bulletin describes the truck, which has a capacity of 6,000 pounds, a two-wheel drive and four-wheel steer, four speeds forward and four reverse.

Interested parties should write to the Elwell-Parker Electric Company, Cleveland, Ohio.

▲ Quigley Company, Inc., has just issued a bulletin on "Insulag". Concrete descriptions of this refractory are given, together with charts indicating the heat savings effected by Insulag and its efficiency.

Interested persons should write for Bulletin No. 327-C, addressing inquiries to the Quigley Company, Inc., 56 West 45th Street, New York.

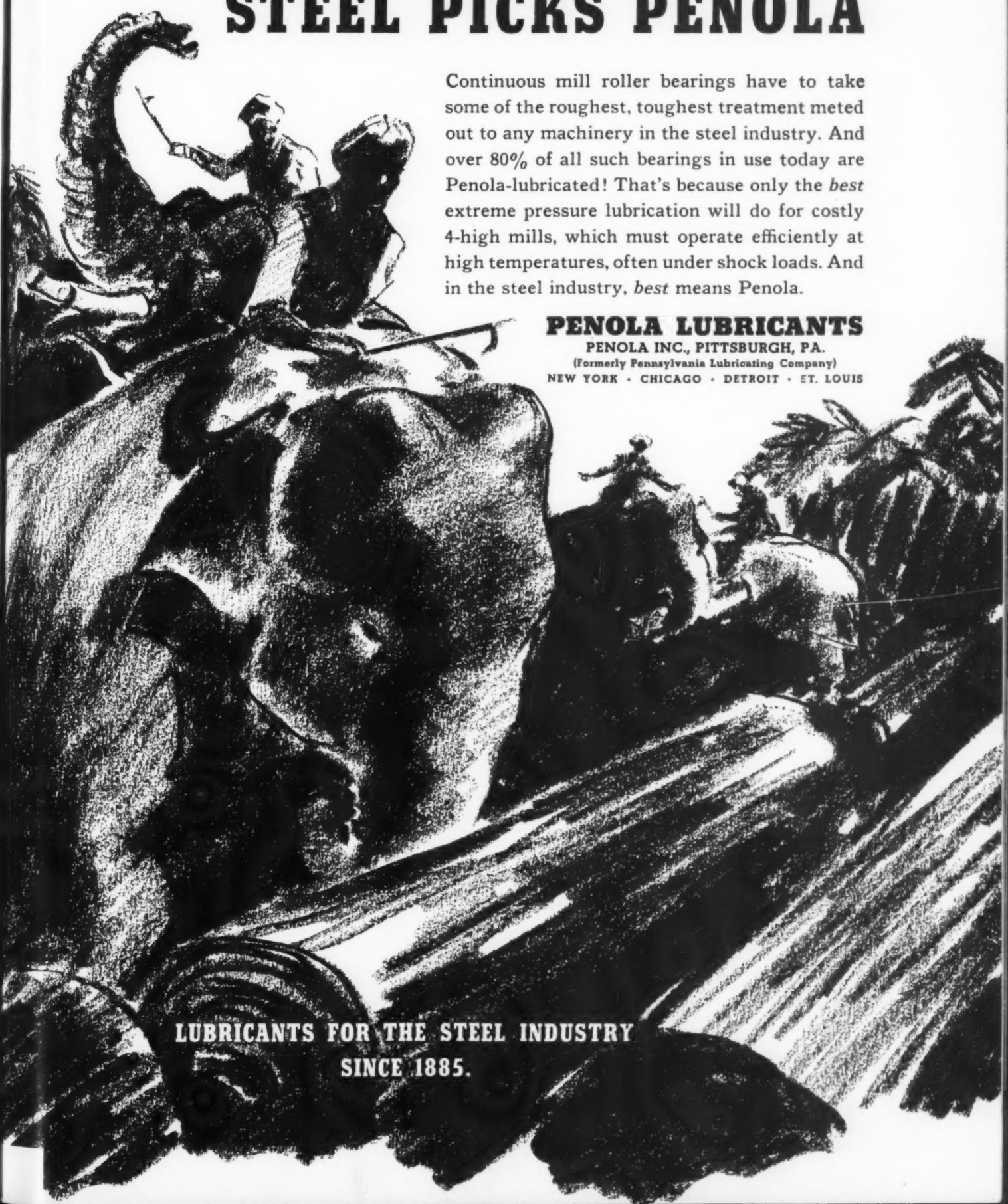
A SLAB MILL had serious trouble with a dense scale that the high pressure sprays could not knock off. A Hays Supersensitive OT Draft Recorder was installed which revealed a large amount of oxygen being fed into the furnace during the charging period. The pressure was adjusted to plus 5/100 in., water-scale was practically eliminated and production noticeably increased.

Two draft values, two pressure values, two differential values, or a combination of any two of these three values may be recorded. These "OT" Recorders are sensitive enough to register accurately increments of .0025 in. water yet are husky enough to stand up under the jars and dirt of steel mill operation. Send for Bulletin 37-232.

Write Dept. 11-7-8

The HAYS CORPORATION
SINCE 1901 COMBUSTION INSTRUMENTS AND CONTROL
MICHIGAN CITY, INDIANA, U.S.A

FOR HEAVY ROLLING STEEL PICKS PENOLA



Continuous mill roller bearings have to take some of the roughest, toughest treatment meted out to any machinery in the steel industry. And over 80% of all such bearings in use today are Penola-lubricated! That's because only the *best* extreme pressure lubrication will do for costly 4-high mills, which must operate efficiently at high temperatures, often under shock loads. And in the steel industry, *best* means Penola.

PENOLA LUBRICANTS
PENOLA INC., PITTSBURGH, PA.
(Formerly Pennsylvania Lubricating Company)
NEW YORK · CHICAGO · DETROIT · ST. LOUIS

LUBRICANTS FOR THE STEEL INDUSTRY SINCE 1885.

John B. Tytus

INVENTOR of CONTINUOUS SHEET ROLLING PROCESS

is Honored

▲ A GREAT industrial festival which rivaled in splendor and completeness the famous crop fextivals of other parts of the country was held in Ashland, Kentucky, on October 19 in honor of John B. Tytus and the world's first continuous rolling mill which he and his American Rolling Mill Company associates helped develop there 15 years ago.

The program began with a parade in which more than 7,000 persons passed in review before Geo. M. Verity, founder and board chairman of Armco; Charles R. Hook, Armco president; Tytus, Armco vice-president in charge of operations, Governor A. B. Chandler of Kentucky, and other prominent industrial and civic leaders.

Talks in the afternoon were given by John H. VanDeventer ,editor of Iron Age; Charles R. Hook; Gov. Chandler, and C. S. Lake, assistant to the president of the Chesapeake & Ohio Railroad. These speakers stressed mainly the advantages which the continuous rolling process has brought to the average person; how by halving the cost of sheet metal, it has increased the purchasing power of all sheet steel consumers by 100 per cent.

VanDeventer characterized the development of the continuous rolling process as the answer to the most urgent of present and future needs—"the need for a low-cost method of producing the most flexible and versatile of all materials, sheet metal".

As proof that the continuous process has provided more jobs at higher pay, Hook pointed out a 31 per cent increase in the number of steel workers from the boom year of 1929 when they totalled 458,887 to 1937 when they numbered about 600,000, and an average wage which in Ashland had increased from 67 cents an hour in 1923, before the continuous process was perfected, to over $1.00 an hour today.

Gov. Chandler pointed out the good that the Armco organization had done in the Ashland tri-state area as a glowing example of what American industry was capable of accomplishing if unhampered by governmental interference.

An interesting sidelight on the afternoon celebration came when the speaking program was interrupted for the presentation of a giant floral horseshoe to John B. Tytus, inventor of the continuous process for rolling iron and steel sheets, by two young women who represented the wives of Armco employees and Ashland business men.

This gala celebration at Ashland ended with a huge street dance for the public, and a banquet attended by nearly 500 civic and industrial leaders of the community. Speakers included Geo. M. Verity; W. C. Hull, vice-president of the Chesapeake & Ohio Railroad; Calvin Verity, executive vice-president and general manager of Armco, and J. C. Miller, Armco vice-president in charge of raw materials purchases.

Philosophizing on cooperation which has been the basis of Armco's development from the beginning, G. M. Verity pointed to the continuous mill as an achievement in which "every man who could be expected to make a contribution, no matter how small, was given the opportunity.

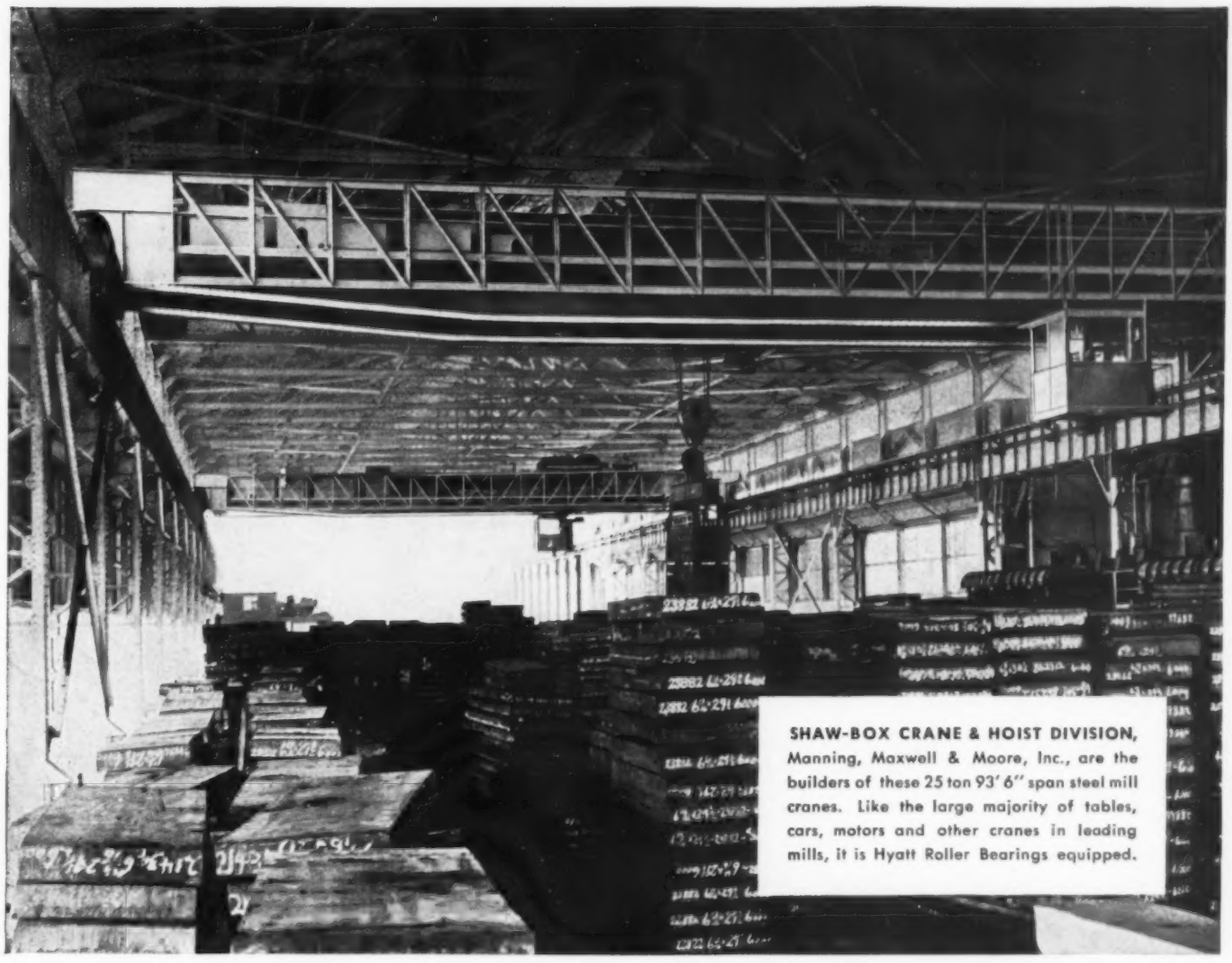
"The whole problem had to be studued, guided and directed by master minders, as is usual in all such undertakings, yet it was the contributions and cooperation of the many that made the project successful beyond all first hopes or anticipations.

"Failure—though other groups had failed—was impossible under such broad cooperative methods as were engendered within the ranks of a new division in our growing industrial organization and throughout this entire community in which they lived and worked".

Women of the tri-state area presented John B. Tytus a huge floral tribute at the afternoon celebration.

Charles R. Hook addressed the great throng that attended the celebration.

ADVERTISING PAGES REMOVED



SHAW-BOX CRANE & HOIST DIVISION, Manning, Maxwell & Moore, Inc., are the builders of these 25 ton 93' 6" span steel mill cranes. Like the large majority of tables, cars, motors and other cranes in leading mills, it is Hyatt Roller Bearings equipped.

Scarcely Aware of Their Presence . . . So Efficiently Do Hyatts Serve

Steel mill engineers who each year specify thousands of Hyatt Roller Bearings for their equipment, new and change-over, know the incalculable performance values contributed by Hyatts. They further know how equally priceless to their equipment is the care-free long life these better bearings afford, even though the operators scarcely realize their presence, so dependably and efficiently do Hyatt Roller Bearings always serve. No wonder Hyatts are so extensively used in steel mills. Hyatt Bearings Division, General Motors Corporation, Harrison, New Jersey, and San Francisco. Hyatt Roller Bearing Sales Company, Chicago and Pittsburgh.

HYATT ROLLER BEARINGS

ITEMS OF INTEREST

Carnegie-Illinois Steel Corporation has announced the following appointments of supervisory personnel at the new Irvin Works, near Clairton, Pa.:

E. T. Lorig, as chief engineer;

R. J. MacKenzie, as assistant chief engineer;

A. L. Billeter, as division superintendent, flat products finishing;

A. C. Bledsoe, as superintendent of cold reduction;

Glenn R. Braddock, as chief order clerk;

John S. Alter, as assistant chief metallurgist;

F. L. Schwearingen, as construction engineer;

A. J. Berdis, as appropriation control engineer;

Klaus Egge, as chief design engineer;

Samuel B. Webster, as project engineer;

J. W. Bates, as electrical engineer;

W. H. Dailey, as power and fuel engineer;

A. C. Grunke, as maintenance foreman, flat products finishing division;

James V. Mazurie, as maintenance foreman, hot strip mill;

Michael C. King, as foreman, tin house and white pickler;

R. H. Crowthers, as warehouse and shipping foreman flat products finishing division;

Alfred Powell, as slab yard foreman, hot strip mill.

▲

Robert A. Peterson was made superintendent of the salvage department, Carnegie-Illinois Steel Corporation, Gary, Indiana. Mr. Peterson first started with United States Steel Corporation subsidiaries in 1934 as rolling mill advisor for the American Steel and Wire Company after four years as manager of heavy mill sales for Aetna-Standard Engineering Company and ten years as superintendent of erection for Morgan Construction Company. In 1936 he joined the Gary Works organization as assistant superintendent of the merchant, wheel and axle mills and a year later he was made superintendent of the merchant bar mill, the position he held until the present time.

▲

J. Donald Rollins has been appointed assistant chief estimator in the engineering department, Carnegie-Illinois Steel Corporation, Gary, Indiana. Mr. Rollins has been associated with United States Steel Corporation subsidiaries since 1934, when he was employed as a junior draftsman and estimator by the American Sheet and Tin Plate Company at Pittsburgh. Coming to Carnegie-Illinois in 1936, he was employed as an estimator for approximately a year in the Pittsburgh office until his transfer to Gary Works in the same capacity. He held this position until his recent appointment. Before his service with the Corporation he had been employed in refrigeration service.

▲

Robert E. Dittrich was appointed assistant to division superintendent of coke plant and blast furnaces, Carnegie-Illinois Steel Corporation, Gary, Indiana. Mr. Dittrich began work as a clerk in the industrial relations department at Gary Works in 1930, and remained in that capacity until his present position.

▲

Roy J. Leckrone has received the appointment to chief designing engineer for the Lewis Foundry and Machine, a division of the Blaw-Knox Company, Pittsburgh, Pennsylvania. Mr. Leckrone has been connected with the various fields of the steel and allied industries since he left the University of Penn-

A. L. BILLETER

ROBERT A. PETERSON

ROY J. LECKRONE

sylvania. He spent three years in Russia designing and building American type of rolling mill equipment. At Lewis Foundry and Machine Division he will serve in both a sales and engineering capacity, and will be located at the company's plant at Groveton, Pennsylvania.

▲

A. J. Hazlett was appointed manager of the strip-sheet sales department of the Jones and Laughlin Steel Corporation, Pittsburgh, Pennsylvania. He succeeds William Miller who was recently appointed district manager of the corporation's Detroit office.

A. J. HAZLETT

Mr. Hazlett has been president of the Eastern Rolling Mill Company, Baltimore, Maryland, since 1927. His entire business experience has been in the steel industry.

▲

Charles Knupfer was appointed vice-president and a member of the board of directors of the Carborundum Company, Niagara Falls, New York. Mr. Knupfer, a native of Rochester, New York, was educated at the University of Rochester. He joined the Carborundum organization in 1907, and was sent to Europe as special sales representative. He was located in Dusseldorf, Germany, until 1915 when he returned to this country and acted as district sales manager at Philadelphia. After the World War he returned to Europe and his continental sales work. In 1936 he was recalled to Niagara Falls where he took over the duties as general sales manager during the long illness of the late George R. Rayner.

▲

Henry P. Kirchner was elected vice-president of the Carborundum Company, Niagara Falls, New York. Mr. Kirchner, born in Buffalo, New York, graduated from the University of Pennsylvania. He taught at the university for a year then came to Niagara Falls and entered the employ of the Niagara Falls Power Company. When the World War broke out Mr. Kirchner went over seas where he spent two years, returning as Major Kirchner. He joined the Carborundum Company, in 1919 as maintenance engineer and in 1927 he was appointed works manager. Mr. Kirchner holds many patents on abrasive products.

▲

William H. Boyle, formerly superintendent, blooming mills, Carnegie-Illinois Steel Corporation, Duquesne, Pennsylvania, has been appointed superintendent of rolling, in charge of bloom, billet and bar mills.

Several other changes at the Duquesne plant are as follows:

Alex Montgomery, Jr., formerly plant industrial engineer, as assistant to superintendent of rolling, in charge of bar mills;

George L. Gallatin, formerly superintendent of bar mills, as chief clerk, order and schedule;

Joseph W. Kennedy, Jr., formerly special engineer, as assistant to superintendent of rolling, in charge of blooming mill;

John W. Jordan, formerly industrial engineer, as plant industrial engineer.

▲

Arthur Batts, secretary of the Carborundum Company, Niagara Falls, New York, has been appointed a member of the board of directors. Mr. Batts joined this company at a very early age in February 1901. For many years he worked directly under Frank Manley, treasurer, in the capacity of accountant. He was appointed assistant secretary and office manager in June 1920. In March, 1927, he was appointed secretary, succeeding the late George R. Rayner, when Mr. Rayner was appointed vice-president.

▲

A. M. MacCutcheon, engineering vice-president of the Reliance Electric and Engineering Company, Cleveland, Ohio, recently sailed from New York for a nine-week business trip abroad.

A. M. MACCUTCHEON

Mr. MacCutcheon is to visit the leading European manufacturers of electric power equipment to study recent developments in design and manufacturing.

ADVERTISING PAGES REMOVED

J. O. Pease, who recently joined the Rockbestos Products Corporation, is representing that company in the New England territory. Mr. Pease will maintain his headquarters in the New Haven office of the Rockbestos Products Corporation.

▲

T. D. Cartledge, formerly assistant general sales manager, has been appointed general sales manager of the Linde Air Products Company, a unit of Union Carbide and Carbon Corporation, 30 East 42nd Street, New York, New York.

▲

deWitt H. Gunsolus was appointed as representative for the furnace division of the Continental Roll and Steel Foundry Company, East Chicago, Indiana. Mr. Gunsolus will handle sales and engineering of industrial combustion equipment and allied furnace accessories manufactured by this division of the company. He will be located at 534 Vine Street, Cincinnati, Ohio.

▲

J. N. Walker has been elected vice-president of Oxweld Acetylene Company, a unit of Union Carbide and Carbon Corporation, 30 East 42nd Street, New York, New York.

▲

Walter Gerlinger, president of Walter Gerlinger, Inc., 610 West Michigan Street, Milwaukee, Wisconsin, has been named as representative of the General Alloys Company, having the entire state of Wisconsin for his territory. Mr. Gerlinger, with the assistance of other members of his organization, will direct the handling of the General Alloys line.

▲

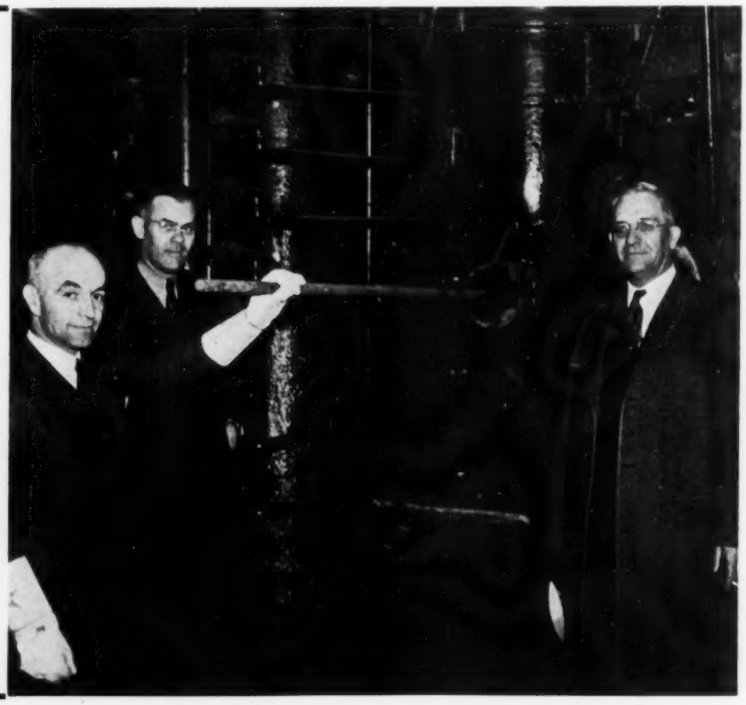
William P. Langworthy was appointed director of the electrical materials division of the Allegheny-Ludlum Steel Corporation. Mr. Langworthy, widely known throughout the industry, was formerly president of the Lamination Stamping Company of Hartford, Connecticut, first and largest specialists in the

WILLIAM P. LANGWORTHY

fabrication of electrical steels. In 1930, the company was merged with Allegheny Steel Company, with Mr. Langworthy becoming manager of the fabrication division, a position he has held up to the time of his present appointment.

Keeping in step with the general improvement in iron and steel production, Republic Steel Corporation has recently blown in the blast furnace at its Canton, Ohio, works. This furnace has undergone extensive rebuilding during the past year. Previous to its shutdown in October, 1937, the furnace had been in operation for approximately four years.

Civic leaders and public officials participated in the ceremonies. The furnace was lighted by James Seccombe, mayor of Canton. In the illustration at the right, C. W. Meyers, district manager, Central Alloy District, is at Mayor Seccombe's left, with C. H. Elliott, assistant vice-president in charge of operations, at the extreme right.



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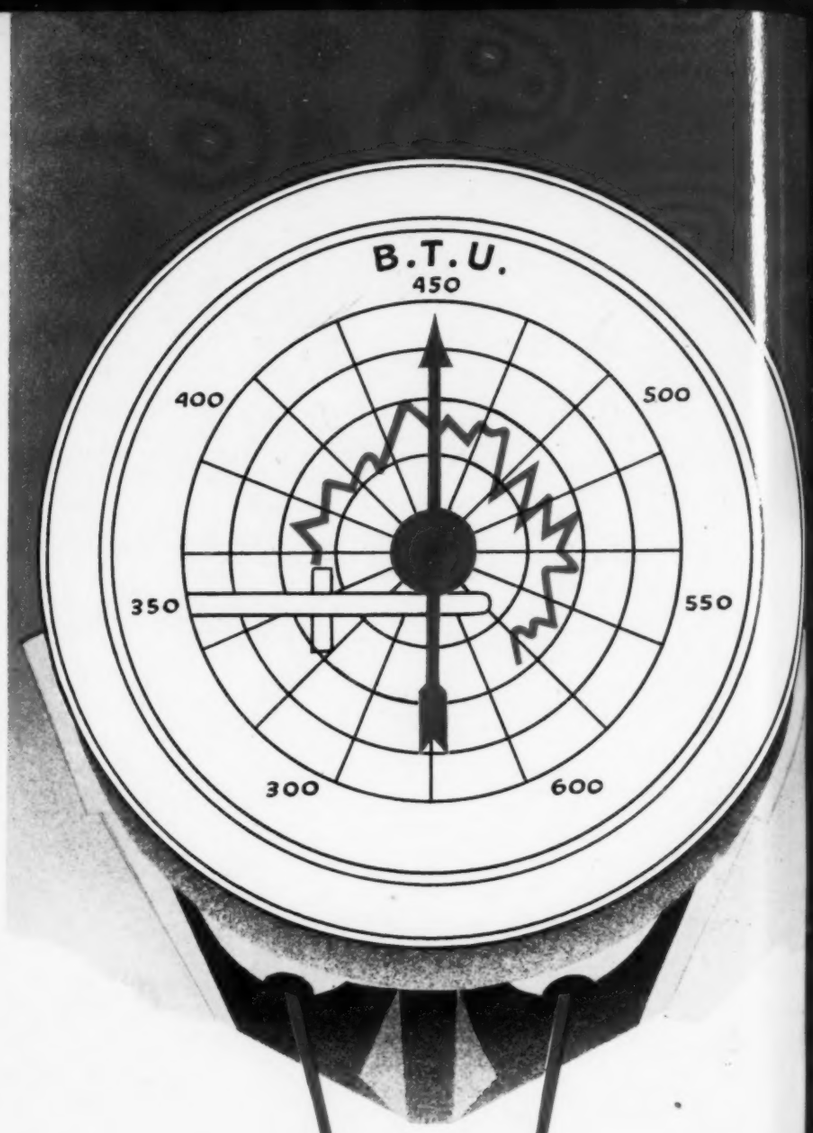

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